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BULLETIN No. 53 PSYCHOLOGICAL SERIES No. 1

THE PSYCHOLOGY OF SKILL

WITH SPECIAL REFERENCE TO ITS ACQUISITION IN TYPEWRITING

BY
WILLIAM FREDERICK BOOK
PROFESSOR OF PHILOSOPHY, UNIVERSITY OF MONTANA
LATE FELLOW IN PSYCHOLOGY
CLARK UNIVERSITY

UNIVERSITY OF MONTANA
MISSOULA
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EDITOR'S NOTE.

The University of Montana Studies in Psychology will be devoted to reports of researches undertaken in the Psychological Laboratory of the University by advanced students and instructors in the department. The results of such investigations as may be carried on will be gathered together every little while and published. The present initial volume of the *Studies* is devoted entirely to the Psychology of Skill. The first two sections of this study in learning, The Learning Curves, and The Analysis of the Learning Consciousness, were, in January 1906, submitted to the faculty of Clark University, Worcester, Mass., in partial fulfillment of the requirements for the degree of doctor of philosophy and accepted on the recommendation of Professor E. C. Sanford. Publication of these parts of the study has, however, been delayed until the entire investigation could be completed. None of the results of the present study have been published hitherto.

Copies of this and future numbers of the *Studies* may be had by addressing the editor, W. F. Book, or The Exchange Department of the University.

Missoula, Montana, December 1st, 1908.

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LAP

THE PSYCHOLOGY OF SKILL

WITH SPECIAL REFERENCE TO ITS ACQUISITION IN TYPEWRITING[1]

I.

INTRODUCTION.

A. THE PROBLEM AND AIM OF THE STUDY.

In making this study of the acquisition of skill a double purpose was kept constantly in mind: (1) To obtain for each of the learners taking part in the study a practice or learning curve which should accurately represent his progress; and (2) to obtain from his self-observations and from objective records of his writing such data as would make possible the explanation of his curves.

Few systematic attempts have been made to determine and describe completely the psycho-physical habits of every kind and order involved in the acquisition of any special skill. And, so far as the writer is aware, no attempt has been made to determine just how these habits are acquired in the learning act. We do not know *how* any special school subject is actually learned or how any specific skill is acquired because no complete psychological history of their learning has been recorded. The admirable studies of learning by Bryan and Harter,[2] Johnson,[3] Swift,[4] Bair,[5] Raif,[6] Ebert and Meumann,[7] and others have, for various reasons been incomplete in this respect.

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[1] This study was begun in the Psychological Laboratory of Clark University, under the direction of Prof. E. C. Sanford. All but the Memory test experiments were made in that laboratory and the writer takes great pleasure in acknowledging his obligation to Dr. Sanford for the many helpful suggestions which he so generously and willingly gave, for constant encouragement and innumerable kindnesses extended during the time this study was being carried on, and for his criticism of the entire manuscript. I wish also to acknowledge my indebtedness to Dr. F. Kuhlmann, University of Illinois, for helpful suggestions in planning the study and invaluable help in devising apparatus. The writer is also indebted to Dr. Louis N. Wilson, Librarian of Clark University, for placing at his disposal many journals and books otherwise inaccessible, and to the University of Montana for providing every other necessary means for completing the work.

[2] Studies in the Physiology and Psychology of the Telegraphic

The present study is an attempt to determine all that took place on the conscious side as skill in typewriting was acquired. Our purpose was to ascertain the habits of every kind and grade involved in its mastery, to find out how these associations naturally formed and developed in the course of the learning, to discover and describe the factors and phenomena that helped or hindered their organization and growth—in a word we tried to delineate accurately and completely, by means of systematic observations (guided and verified by measurable objective data) the path or paths which certain learners took in coming into possession of the skill of an expert typist.

For such an *introspective* study of learning previous investigations have prepared the way. In asking operators "to what their attention had been directed at different stages of efficiency, how far they could copy behind, what they did when special difficulties occurred," etc., Bryan and Harter showed that they already keenly felt the need of a more purely psychological method of getting at the facts relating to learning. In a more recent study of the effects of practice in the realm of memory *(Archiv fur die Gesamte Psychologie,* Vol. IV, 1904, pp. 1-232), Ebert and Meumann got careful observations from their learners on the causes for memory improvement. They compared the total psychic factors involved in the memory act of the early stages of practice with the factors involved in the later stages and had their subjects make careful observations on their method of reading, learning and reproducing the material learned, with the view of determining the exact effects of practice on all these phenomena. Leuba in a study of "Learning to Make Hand Movements" *(Psy. Rev.,* Vol. XII, Nov. 1905, pp. 353-357) carefully analyzed the psycho-physical processes involved in the learning but did not state how these associations

Language, **Psy. Rev.,** Vol. IV, 1897, p. 27. **Psy. Rev.,** Vol. VI, 1899, p. 345.

[3] Researches in Practice and Habit. **Studies from Yale Psychological Laboratory,** Vol. VI, 1898, p. 51.

[4] Studies in the Psychology and Physiology of Learning. **Am. Jour. Psy.** Vol, XIV, 1903, p. 201. The Acquisition of Skill in Typewriting, **Psy. Bull.** Vol. I, 1904, p. 295. Beginning a Language. Garman Memorial Volume of Studies in Philosophy and Psychology, Boston, 1906, pp. 297-313.

[5] The Practice Curve. **Psy. Rev. Mon. Suppl.** Vol. V, 1902, pp. 1-70.

[6] Uber Fingerfertigkeit beim Clavirspiel. **Zeit. f. Psychologie und Physiologie der Sinnes Organum,** Vol. XXIV, pp. 352-357.

[7] Uber einige Grundfragen der Psychologie der Ubungsphanomene im Bereich des Gedachtnisses. **Archiv fur die Gesamte Psychologie,** Vol. IV, 1904, pp. 1-232.

were acquired. Cleveland in attempting "to sketch the psychology of the game of chess and to trace the stages in the development of the chess player" *(Am. Jour. Psy.* Vol. XVIII, July 1907, p. 270) has attempted to do for chess more nearly what is undertaken for typewriting in the present study. But as one of his reviewers says: "The study does not give in sufficient detail the factors of the learning process which are peculiar to chess" *(Psy Bull.,* July 15, 1908, p. 236). We need to know more specifically all that learning means on its psychological side, to get complete and reliable psychological records of the entire process of learning as it actually works itself out in the various fields of acquisition and learning, so that we may *know* how the various forms of skill may be most successfully and economically acquired and the various school subjects most economically learned and taught.

That our task in carrying out such a program for even a single kind of learning is difficult no one can realize better than the writer; how far he has succeeded the reader will judge for himself. Within the limits of his capacity and the facilities at his disposal he has done his best to make his picture complete. The effort for completeness has involved, almost unavoidably, a certain amount of repetition and sometimes the statement of facts of common knowledge. Both of these the writer has, however, reduced as much as he was able and would respectfully refer readers who find these tedious to the summary with which the study concludes.

B. METHODS EMPLOYED.

1. *Apparatus and Learners.*

Apparatus.—Since our aim was the getting of learning curves explicable in detail by checked introspections, we had need first of an accurate record of what each learner did while at the typewriter, and second of a systematic procedure in making and recording his introspections. The first was obtained by means of electrical connections between the machine and three Deprez markers writing upon a kymograph drum in such a way that everything the subject did on the machine was recorded. Every time he struck a letter ("a", Fig. I), every time a word was finished ("b", Fig. I), or the carriage moved back for beginning a line ("c", Fig. I), the fact was recorded so that the time consumed in the performance as well as the manner of

its execution could be determined from the record.[1] By means of a switch key attached to one of the markers and controlled by the experimenter the number of times the learner had to look at the copy as well as the actual amount of time spent in fixing it in memory was likewise recorded ("d", Fig. I). All apparatus was placed on a separate table nine feet away and carefully screened from the learner's view.

But these records of the writing proved insufficient for supplementing and checking the learners' introspections. After some weeks of experimenting on X it was found by introspection that the amount of effort put into the work varied from day to day, even during the course of a single test. A maximum degree of effort could seemingly not be kept up. How hard and successfully a learner tried depended upon many factors, most of which were too subtle for observation. Some objective index of these variations in effort was obviously desirable.

It was thought that a pulse record, though not all that could be desired for such a purpose, might give a fairly reliable measure of whatever fluctuations in effort might occur.[2] With the view of testing this hypothesis and with the hope of getting a reliable index of these variations in attention and effort, an apparatus was devised for getting a continuous pulse record from the learners as they worked. Two small tambours, made in the laboratory, with round cork points cemented to the centers of their rubber surfaces, were placed so as to receive the pulsations of the temporal artery in front of each ear. By means of a specially designed cloth cap and sharp pointed plates soldered on the backs of the tambours the latter were so lightly and securely held in place on the arteries that no movement of the head or body, which occurred during the writing, interfered with their functioning. These receiving tambours were connected by means of rubber and glass tubes to a third tambour which inscribed a pulse curve beside the record of the writing on the drum ("f" in Fig. I). With this apparatus writing

[1] A Jaquet's chronometer was used to mark the time on the drum. This time record enabled us to compare the amounts written in the several minutes of all the tests and to correlate the same with the pulse rate. The drum records of the writing for every test were divided into minute periods by piercing the records with a pin, the written copy divided so as to show the amount written in each minute of all the tests and the results compared (see table IV, p. 124).

[2] As will be seen from the tabular data given in the note on page 14 the practice of Y and Z did not begin until the practice of X was well under way, so that complete pulse records were obtained for all the learners except X.

and pulse records were taken at every subsequent test for all the learners.

To get a reliable norm for measuring the amount of variation in pulse caused by the work, the following method was employed: A careful count of the pulse was taken each day after the subject had seated himself ready for work and been quiet long enough, supposedly, to reduce his heart beat to normal.

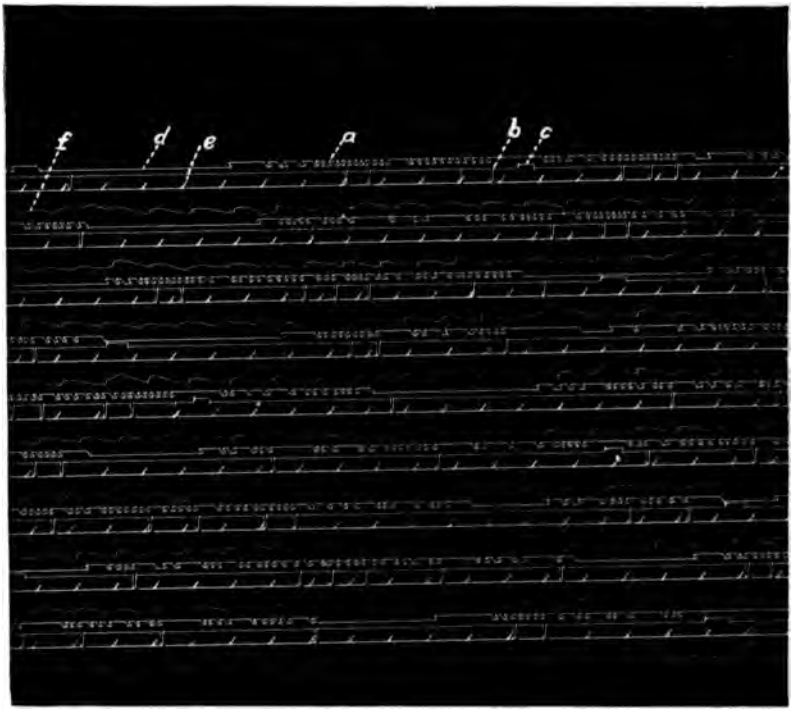

FIG. I

In general five minutes were allowed. Enough counts were then taken (the pulse being counted by the experimenter at the wrist) to insure that the rate recorded as normal was really a normal pulse. After the first two or three weeks practice, when this method was being perfected, no figures were recorded as a normal pulse unless the experimenter had gotten the same result in at least two half minute counts in succession, a minute or two being allowed between counts. In the rare cases where a variation occurred in the final counts the average of the last two or

three counts was recorded as the normal pulse. But with all these precautions and notwithstanding the fact that the two last counts generally agreed, we can, of course, not be sure that an absolutely normal pulse was obtained each day. The average rise of the working over the normal pulse for any particular minute or day is, therefore, not an absolute measure of the variability occasioned by the work. But with the precautions taken, the precision is judged amply sufficient for every use made of the pulse records in this study.

The typewriter used throughout the experiment was an Underwood machine having the "universal keyboard" and visible writing. During the earlier experiments a No. 4 machine was used, later a No. 5. The slight differences between the machines were, for our purpose, unessential. With both machines it was necessary for making capital letters and certain marks of punctuation to press a "shift-key" which slightly raised the carriage, a fact taken into account when measuring the amount of work done for any minute or test (compare p. 18). No change of paper was required for any of the tests, the sheets receiving the writing being regularly lengthened as the learners' skill increased.

All regular tests were executed in the presence of an experimenter who looked after the apparatus and made, during the test, such notes of the learner's general behavior as seemed desirable or significant. For all the tests made on Y and Z and the tests made on all special subjects, the writer served in the role of experimenter, for all tests made upon the writer, Y acted as experimenter.

Learners.—Eleven subjects took part in the experiment, three regular learners, X, Y and Z, three professional typists, four beginners and a typewriting expert. Of the regular learners X first learned to write by the sight method and afterwards by the touch method; Y, who could write at a slow amateur rate by the sight method when the experiment began, learned to write by touch; Z, who had never used a typewriter at all when his practice began, learned to write by the sight method. Y and Z were selected for regular learners because of their special psychological training and past drill in introspection, and because they were so situated that they could give all the time needed to the experiment. Four other subjects who knew nothing about typewriting were taken through the earlier stages of the

learning (two for each method), after the experiment was well under way, with the view of determining still more accurately just how the earliest writing was done and how the first steps of improvement were made. Introspections and a number of records were also obtained from three professional typists (two sight writers and one touch writer), who possessed a greater degree of skill than that acquired by any of the regular learners. Careful introspections and a number of records were also gotten from Miss Carrington, a finished expert.[1] By the help of the records and observations of these special subjects the history of the learning process was followed from the beginning to the most expert stage.

As far as possible the learners were kept ignorant of their scores because it was feared that a knowledge of their score might prejudice their daily observations. They might unconsciously be trying to find reasons for their slow or rapid improvement instead of observing what was actually taking place in consciousness. All they knew about their score was what they could learn by glancing at their written page when the test was finished, a regular habit for the period when improvement was rapid and steady, but no longer reported in the experimenter's notes when the pages began to look so much alike that it was well nigh impossible to tell by inspection whether a higher or lower score had been made.

2. General Procedure and Program for Introspection.

(a) Experiments on the Sight Method.—As already stated both methods of learning, the socalled Sight Method and the Touch Method were studied.[2] In the S. M. learning two subjects, X and Z, neither of whom had ever used a typewriter

[1] The two sight writers could copy at an average rate of 40 to 45 words per minute; the touch writer could write 50 words a minute; Miss Carrington, who won the medal at both the Buffalo and St. Louis Expositions for being the fastest and most expert typist up to those dates, could easily write from any kind of straight copy 70 words per minute. She had won several international contests in blindfold typewriting, and up to March, 1906, was the champion typist of the world. On that date the world's record was broken by Miss Rose I. Fritz of New York, who made in an hour's test a record of 3857 words correctly written.

The writer gladly takes this opportunity to express his grateful obligation to Miss Carrington and his other subjects, especially to Dr. F. Kuhlmann of the University of Illinois and to Dr. E. Conradi, who filled with all patience the long and fatiguing role of learners.

[2] Hereafter instead of the words "Sight Method" and "Touch Method" their initial letters, S. M. and T. M. will be used.

before, co-operated. After a few general directions as to what they should do they were given their first practice and test. A half hour's test was taken each day. At the close of the first and second ten minutes of the test, "time" was called by the experimenter, the learner marking the close of the ten minute period by striking three times a certain key so that the amounts written in each third of the tests might be compared. These half hour sessions continued in the case of X through 174 consecutive days of practice, Dec. 19, 1904, to June 22, 1905; for Z through 86 actual practice days, Mar. 14, 1905, to June 22, 1905.[1]

In addition to this general training there was started for each learner, soon after his regular writing tests began, the writing of a special "practice sentence,"—"A quick brown fox jumps over the lazy dog" (learners X and Z in their S. M. practice, Y in the T. M.) or "Pack my box with five dozen liquor jugs" (learners Y in S. M., X in T. M.)—embodying all

[1] Owing to trouble with apparatus, sickness and other unavoidable causes sessions had to be omitted for X on Dec. 24 and 25, Jan. 28, 29 and 30, Feb. 15, Mar. 25, May 25, and June 9. For Z on Mar. 19, Apr. 23 and 30, May 7, 16 and 23, June 1-5, 11 and 18.

In order to facilitate reference the chief dates in the history of the experiment are given in tabular form below:

TABLE I.

REGULAR WRITING

Subjects	Practice begins	Practice ends	Total No. of tests	Length of practice period	Method of study used	Date of Beginning of pulse record
X	Dec. 19, '04	June 22, '05	174	30 minutes	S. M.	Feb. 16, '05
X	Nov. 17, '05	Jan. 16, '06	60	10 minutes	T. M.	No pulse record taken.
Y	Mar. 1, '05	July 29, '05	130	10 minutes	T. M.	Mar. 1, '05
Z	Mar. 14, '05	June 22, '05	86	30 minutes	S. M.	Mar. 15, '05
		PRACTICE SENTENCE WRITING				
X	Jan. 1, '05	Mar. 15, '05	70	Wrote sentence 120 times per day	S. M.	No pulse record
X	Nov. 20, '05	Dec. 30, '05	40	Ditto	T. M.	" " "
Y	Dec. 30, '04	Feb. 20, '05	51	20 minutes	S. M.	" " "
Y	June 6, '05	July 29, '05	40	10 minutes	T. M.	June 6, '05
Z	April 13, '05	June 30, '05	61	10 minutes	S. M.	April 13
		MEMORY TESTS				
X 1.	June 1, '06	June 10, '06	10	10 minutes	T. M.	No pulse
X 2.	June 1, '07	June 10, '07	10	10 minutes	T. M.	" "

the letters of the alphabet, because this promised to give in miniature the whole story of the learning. Z wrote the first of these sentences ten minutes each day for 61 days, all his practice on it being in the form of a test of which a drum record was taken. X wrote the same sentence 120 times each day for 70 days or until a physiological limit was approached. At a regular time each day a drum record was taken of twenty executions of the sentence to test the progress and speed of writing, the other practice being taken at his convenience and at any rate of speed desired. The same conditions prevailed in Y's writing of the practice sentence. The general observations for determining how the writing was done were made during this general practice when there was no trial for speed.

This practice sentence writing together with the half hour daily tests and some three or four hours writing, at irregular intervals every eight or ten days, for purposes of special introspective analysis, constituted the total practice of the subjects learning to write by sight.

(b) Experiments on the Touch Method.—For the two subjects learning to write by the T. M., X and Y, the conditions were the same except that the regular daily tests lasted ten minutes only and the total daily practice amounted to one hour including the ten minute test. No special periods for introspection were required in this method since all necessary introspections could be made during the regular fifty minute practice period each day. The regular tests on Y began Mar. 1, 1905, and continued 130 days. With the exception of a break in the practice from Mar. 22 to Apr. 6, caused by sickness in his home, another from June 27 to July 1, caused by trouble with apparatus, his practice was continuous. X began his T. M. practice Nov. 17, 1905, and continued uninterruptedly for 60 days. In addition to the regular practice Y wrote the practice sentence, "A quick brown fox jumps over the lazy dog," ten minutes each day for a period of 40 days. All his practice on it being in the form of a test the same as for the S. M. practice of Z. X wrote the sentence, "Pack my box with five dozen liquor jugs," 120 times a day until he could write it at the rate of 100 words per minute. This constituted the total practice of the T. M. learners.

During all the T. M. writing, for both kinds of practice, the keys were covered by a thin board fastened to a standard in

such a manner that free movement of the hands was allowed while it shut out completely every part of the keyboard from the view of the learners.

All tests were taken at the same time of day, Z's S. M. tests at 2:00 in the afternoon, X's S. M. tests at 4:00, Y's T. M. tests at 4:30, X's T. M. tests at 8:00 in the morning. In a few cases these times had to be slightly varied. The last fifteen regular tests of Y were taken at 9:00 A. M. The fifty minutes daily practice of the T. M. learners was also taken at a fixed time of day and always after the daily tests.

Except for the "practice sentence" all writing for both methods of learning was from copy. Three plain articles in the *American Journal of Psychology* and Munsterberg's book, "Psychology and Life," furnished the material copied.

(c) Program for Introspection.—Two kinds of introspective data were gathered. At irregular intervals of from eight to ten days (in the first stages of learning much oftener) the learner was set to copying for the express purpose of observing how the writing at that stage was done. These periods, which, it will be remembered, were used only with the S. M. learners—the special fifty minute practice periods each day in the T. M. writing serving a similar purpose in that method—lasted from one to three hours at a sitting with short periods of rest taken whenever the subjects began to feel fatigued. Special care was always taken that all this writing be at a maximum rate as in the regular tests. In all these introspective sessions a specific point was focussed upon and carefully worked out before another problem was taken up. For example the learner first determined how he located the keys or what sort of spelling he did before taking up some other point. If, however, when any special point was being worked out, another fact of interest was observed, it was immediately recorded whether it related to the particular problem considered at the time or not. No questions were asked the learners during these special practice periods though a schedule containing a list of the problems to be worked out, or topics with reference to which information was desired was kept before them. They were alone in the room and tried during these special introspective periods to get a complete analysis of the learning consciousness for that stage of advancement.

A second sort of introspective data gathered consisted of the notes written down at the close of each day's test. It was a

part of the regular program to have each learner write down, immediately after finishing a test, any facts which he had observed during the course of the experiment, either on the manner of doing the work or on what had helped or hindered his progress that day. After this he was usually questioned about certain points which the writer had found from previous observations or from the objective records, to be important. This data, while covering the whole field, and containing many facts important for the analysis of the learning consciousness, showed more specifically the conditions which helped or hindered the acquisition of the special habits formed. The important points thus elicited were always made the subject of further study in the special introspective periods.

In getting reliable introspective data for such a complex process as learning, many difficulties are encountered as every one knows, difficulties which make it necessary to exercise every precaution. In the preliminary tests it was found that a learner was specially prone to overlook some of the more important facts pertaining to the analysis of the learning consciousness, even if he escaped the greater danger of giving wrong emphasis to the facts observed. To be reliable the learner's self-observations should be verified by authentic objective results. Such verification was, in the present experiment, given by the drum records of the writing already referred to. These served not only to verify but to direct, supplement and enrich the observations of the learners. A second well know difficulty encountered in getting reliable introspective data is to keep consciousness from concerning itself with the observing act. This was met in the present experiment by having each learner take care always to write at a maximum rate and without thinking of how the work was done or of how attention was working, frequently stopping to turn attention backward to see just how the work had been done. By having a definite point in mind to observe, the facts could, in this way, nearly always be determined and redetermined until the subject was sure of the truth of his observation when he stopped writing to make note of it.

C. RESULTS.

From what has been said it is clear that our results will include (1) a group of individual tables and learning curves picturing more or less accurately the progress in learning made

in both the regular learning and in the writing of a practice sentence. (2) The special introspective notes and records of the writing which show how the work was done in all stages of advancement, the analysis of the learning consciousness for all stages of practice. (3) A group of objective and introspective facts pertaining to relearning and the retention of typewriting skill.[1] (4) The facts revealed by the daily notes which, with certain objective data, enable us to determine the phenomena which conditioned the learning and rate of work in our experiments. These facts must all be set forth in detail before we shall be able to understand or explain our learning curves. For sake of clearness they will be grouped and treated in the order named.

II.

THE LEARNING CURVES.

One net result of our objective data[2] is, as we have said, a group of individual tables[3] and learning curves. In determining the progress made by our learners, the actual number of strokes made on the machine during a test was taken as the measure. To get a still more accurate measure of the amount of work done the following method of evaluating the strokes was used. Each letter and mark of punctuation, not requiring a shift of the carriage, was counted as one stroke; striking the word spacer was counted as half a stroke; making a capital or any mark requiring the use of the "shift key" was counted as two strokes; moving the carriage back to make a line was counted as three strokes. On the basis of the total number of strokes made in the several daily tests the learning curves were drawn. The result or progress made by the learners is graphically shown in Fig. II, below.

To facilitate comparison the curves are all drawn on the same scale. The number of days of practice is shown on the

[1] For the account of the experiments made in the "Memory Tests," see section IV, p. 75 below.

[2] The drum records of the writing were also used in determining how the writing was done in the different stages of advancement and in ascertaining how the various associations formed, developed in the course of the learning. Compare Fig. V, p. 88.

[3] The data obtained from the drum and machine records of the writing was arranged in the form of individual tables, one for each kind and

horizontal axis, the amount of work done (in strokes) on the vertical axis, for curves "A," "D" and "E" to the left and for curves "B" and "C" to the right. The figures on the horizontal lines under the curves represent the average rise in pulse above the normal for the period of practice indicated by the length of the line on which the figures are placed. Curve "A" represents Y's regular T. M. practice; "B" X's regular S. M. practice; "C" Z's regular S. M. practice; "D" X's regular T. M. practice; "E" Y's writing of a practice sentence (T. M.,)[1] "F" X's regular T. M. curve (same as curve D) and the first part of Y's T. M. curve drawn to the same scale. To show the individual features of these T. M. Curves, X's regular T. M. curve (D Fig. II) had to be pushed higher up on the scale than it rightfully belongs. Each point in this curve as measured by the vertical scale to the left is just three hundred strokes higher than it should be. Because these T. M. curves practically coincide (curves "F") for the first sixty days of practice, curve D was started higher up on the scale.

It will be seen that these curves are in their main features similar to those obtained by previous experimenters. There is in all a rapid and continuous rise in the early stages of practice followed by a slower and more gradual rise in the later stages. All show marked daily variations picturing the fluctuations in the learner's ability to do what might be assumed to be the same task under constant objective conditions. In addition to these daily variations there are in all of the curves short periods of non-improvement lasting from six to eight days, *"Breathing Places"*[2], as it were, where the learners for a time made no

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method of writing. These tables showed, in addition to the date and total score of each test, the normal pulse for the day, the average working pulse for each successive minute of every test, the average working pulse for the whole test, the average rise of the working over the normal pulse, the number of strokes made on the machine in each successive minute of all the tests placed along side the corresponding pulse record for the minute, the total number and per cent of errors made that day, etc., etc. But since these tables were long and somewhat technical they will be omitted and the important facts they revealed shown in other ways. The original tables will be kept in the Montana Laboratory and a copy deposited in Clark Laboratory for reference. (See sample records Table IV, p. 124).

[1] For other typical curves showing the progress made in writing a practice sentence, see Figs. VII, VIII, pp. 112-113 below.

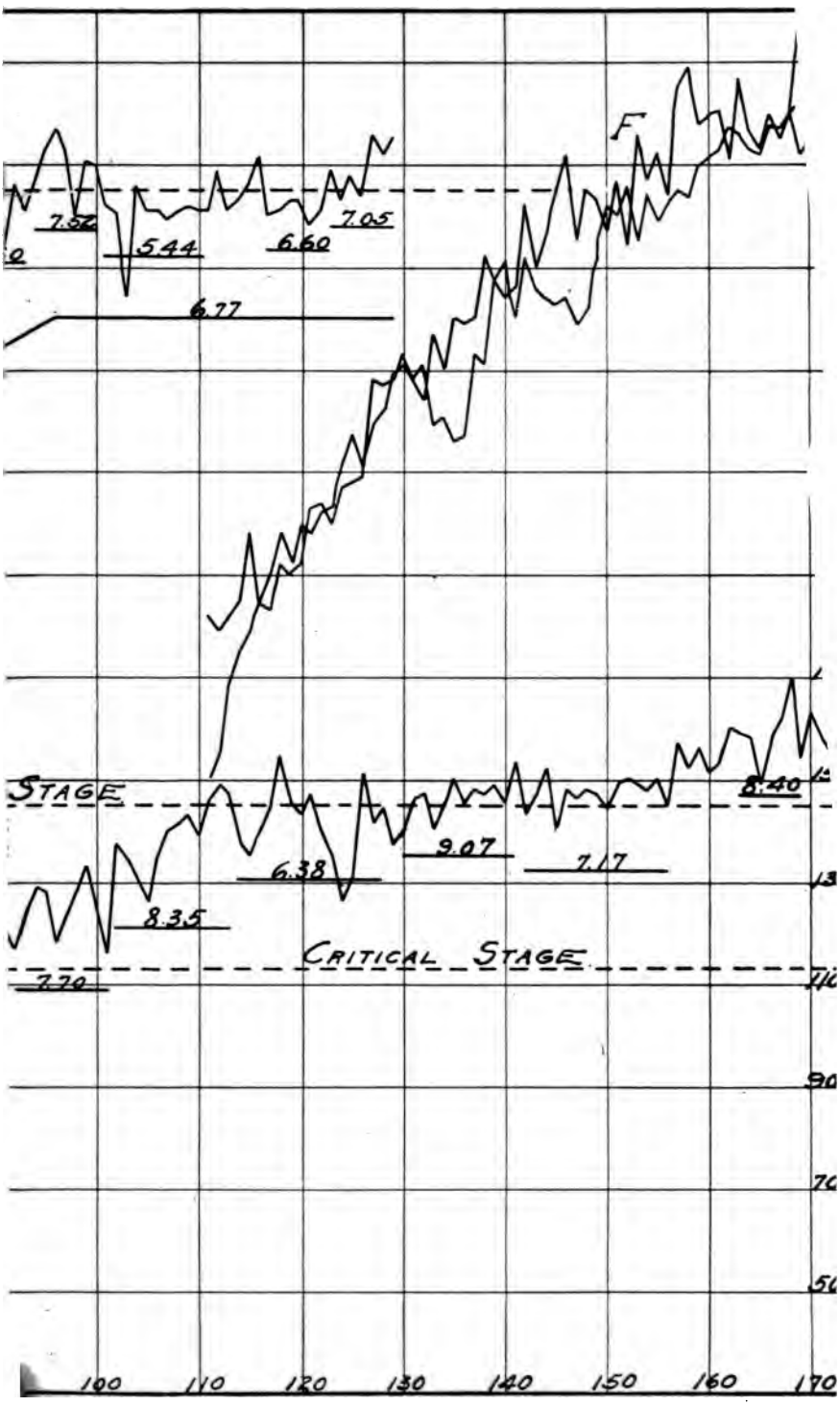
[2] It has been customary to call all arrests of progress by the general name of "plateau"; but to the writer's mind this obscures a real difference in character and causation (see pp. 139-148), a fact which he has tried to emphasize by employing a new term for these shorter periods of arrest.

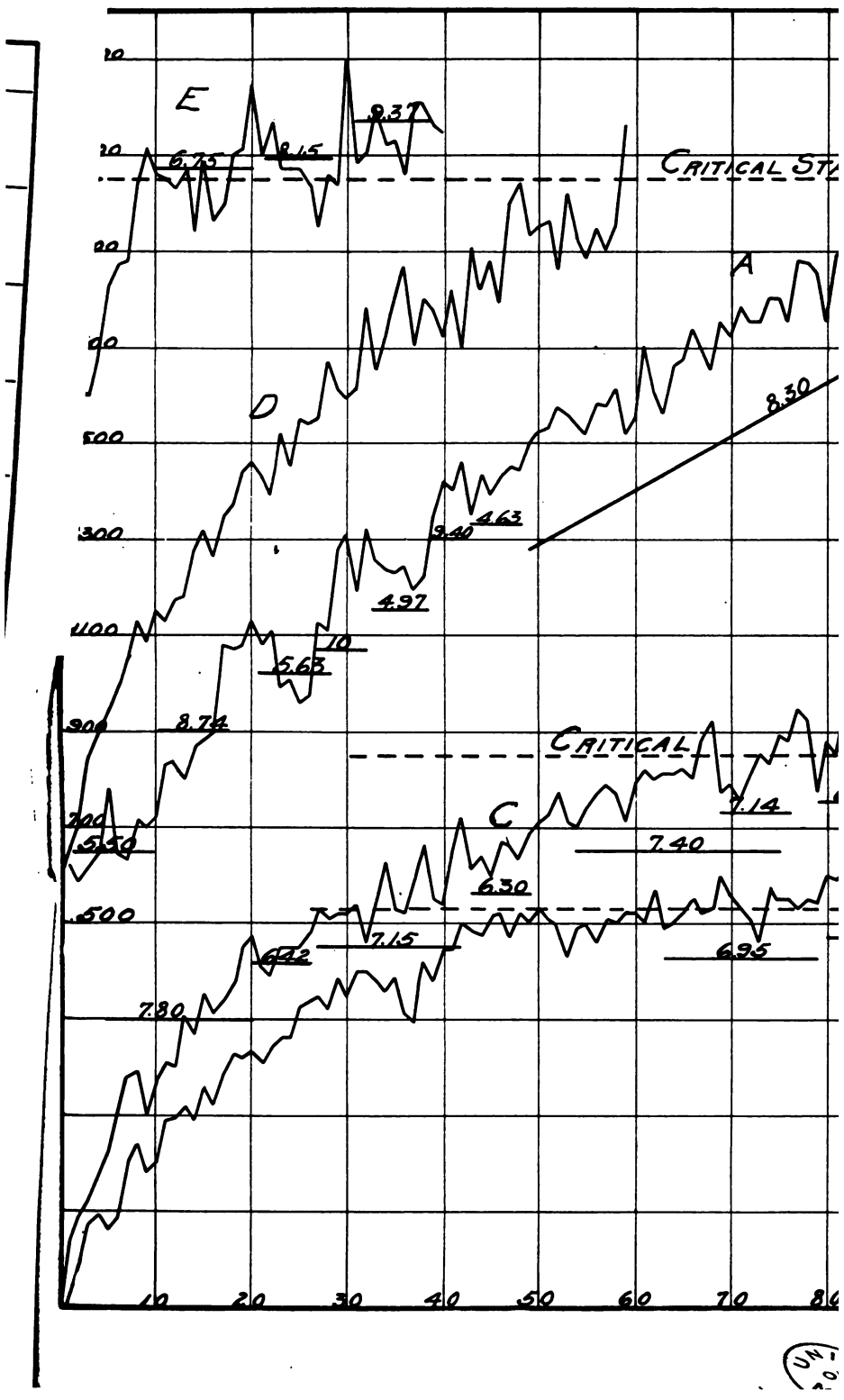
determinable improvement, often falling below their best records for previous days.

In addition to these more general features the curves reveal certain individual features not common to all. Two of the curves, for instance, X's S. M. curve (B, Fig. II) and Y's T. M. curve (A, Fig. II) show one or more distinct *plateaus,* periods of arrest longer than the "breathing places" just mentioned, where the learners for stretches of from 17 to 33 days made no measurable improvement. The T. M. curve of X (D, Fig. II), on the other hand, and the S. M. curve of Z (C, Fig. II) show no plateaus. It is significant that these curves represent shorter periods of practice, the former but 60, the latter 86 practice days, while the S. M. curve of X and the T. M. curve of Y represent respectively 174 and 130 days.

It may also be observed that even the general features of the curves vary with the different learners. There are more of the "breathing places" in some cases than in others and they do not come at corresponding stages of advancement while the plateaus, on the other hand, seem to belong to rather definite levels of attainment. Again, the daily variations in the S. M. curve of X, for instance, seem less pronounced and variable than for the other subjects while his progress as a whole is much less steady and continuous than that of the other subjects, notably that of Z. It will be noticed that the curves of Y and Z rise much more steadily and rapidly than the S. M. curve of X; Z attained a skill in 60 days (C, Fig. II) that it took X 140 days to attain (B, Fig. II), notwithstanding the fact that X was more intently interested in the experiment and doubtless tried harder than did any of the other learners. The difficulties which he encountered after 46 days of practice causing a plateau of 33 days duration in his curve, Z seems to have escaped or met successfully, for his curve rose rapidly and steadily almost to the end of his practice.[1] With the exception of four short "breathing places," a partial arrest from the 20th to the 27th day (6da.), another between the 41st and 49th (8da.), a third between the 67th and 76th (8da.), and a final drop in the curve during the last six days of his practice, Z's progress was rapid and continuous. X's S. M. curve (B, Fig. II) representing the

[1] In this connection it is interesting to note that Z was the same subject who worked out the ingenious method of learning and showed such characteristic adaptability in Swift's Ball Tossing Experiment, **Am. Jour. Psy.** Vol. XIV, 1903, pp. 201-222, Subject, E.


F
7.52
5.44
6.60
7.05
6.77
STAGE
6.38
9.07
7.17
8.40
8.35
CRITICAL STAGE
7.70
100
110
120
130
140
150
160
170


E
6.75
8.15
9.37
CRITICAL ST
A
D
8.30
4.63
9.40
4.97
5.63
8.74
CRITICAL
7.14
C
7.40
6.30
7.15
6.95
7.80
10
20
30
40
50
60
70

same method and external conditions is quite different. Before the plateau above mentioned had set in there had been two "breathing places" in his curve, a period of six days beginning at the 17th day, and another halt of eight days beginning with the 29th. His second period of rapid improvement began after he had practiced 80 days and lasted 32 days (Mar. 17, Apr. 19), when a second plateau, extending over a period of 32 days, (April 19, June 3), began. On the 153rd day another period of decided improvement set in lasting 16 days. This was followed by a final drop in the curve the last six days.

As previously stated the plateaus seem to belong to definite stages of advancement. X's first plateau occurred when he was writing at an average rate of 110 to 120 strokes a minute. A glance at the diagramatic curves in Fig. III will show that Z's progress (upper curve) was noticeably checked, though not arrested, at this same stage of skill. His rate of improvement

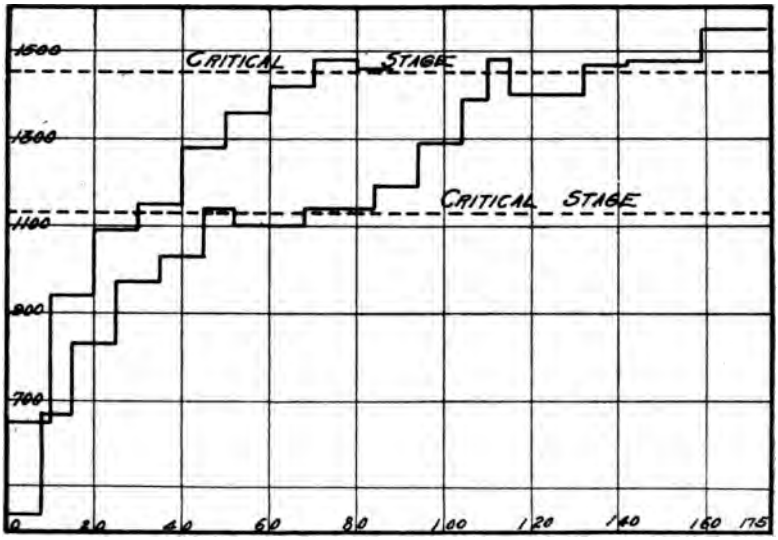


FIG. III.

In these diagramatic curves of the S. M. writing of X and Z, the horizontal parts of the curves represent, when measured by the horizontal axis, the number of practices represented, when measured by the vertical axis, the average number of strokes made upon the machine each day for the periods of time indicated by the length of the lines in horizontal direction. The vertical parts of the curves are mere connecting links. The upper curve represents Z's regular S. M. practice, the lower the S. M. practice of X.

was noticeably slower at this stage than for a period of similar length immediately before and after (compare also curves B and C, Fig. II). This, too, when it was clear that he was trying harder for the period of slow improvement than for the period of practice immediately preceding and following this stage, both of which showed more rapid gains. The period of slow rise for Z and the first plateau for X mark the first distinctly "critical stage" encountered in the S. M. learning. A second plateau occurred in X's S. M. curve when he was writing at an average rate of 145 strokes a minute. Z had just reached this rate of speed when unfortunately his practice was stopped, but there was every indication in his notes and curve that his progress would have again been checked, if not entirely arrested had he continued, by the peculiar difficulties encountered at this stage.

Y's T. M. curve (A, Fig. II) is in character somewhat of a compromise between the S. M. curves of X and Z. With the exception of four "breathing places" from the 19th to the 25th days of practice (6da.), from the 32nd to the 38th (6da.), from the 42nd to the 48th (6da.), and from the 51st to the 59th (8da.), his curve rose rapidly and continuously for 97 days, after which there was a plateau extending over a period of 32 days. There was, following this, every indication of another rapid rise in his curve, but at this point his practice was broken off.

X's T. M. practice was stopped at the end of 60 days, so that his curve (D, Fig. II) is only comparable in part with that of Y, which represents a practice period of 130 days. Y's curve showed, as we have said, some three or four "breathing places" in its regular upward course. X's T. M. curve, on the contrary, shows a rapid and almost continuous rise for the entire 60 days. Only two "breathing places" occur in his T. M. curve. Whether X's curve would have shown a plateau at the second "critical stage" as did the curve of Y, it is impossible to say. The facts, that X and Y had both previously learned to write by the S. M., that both successfully overcame the first "critical stage" in their T. M. writing, and that the plateau in Y's practice sentence curve (E, Fig. II) occurred at the same level of attainment as in his regular practice (when he was writing at a rate of 205 strokes per minute), are significant and will be treated later (p. 166) in detail.

The curves picture the general character of the progress made by each learner and show his actual "ability to do" from

day to day, week to week and stage to stage of the practice. To explain them fully we must not only determine to what their general rise is due, but account for all their salient features and individual peculiarities. What do these curves mean psychologically? What associations and habits were formed making possible their general rise? How were these associations and habits developed and perfected in the course of the practice? What factors helped or hindered their formation and growth? To a consideration of these questions we now must turn.

III.

ANALYSIS OF THE LEARNING CONSCIOUSNESS.

Psycho-physically speaking the learning of typewriting means the acquisition of a group of special habits. Of these we may for convenience distinguish two sorts, *Habits of Manipulation,* the more purely psycho-physical habits involved in the mastery of typewriting, and *Habits of Control,* certain general or more purely psychic habits acquired in the course of the practice. Of these we shall speak in their order.

The Habits of Manipulation are of all kinds and degrees ranging from the simple and elementary associations involved in the writing of a beginner, to the complex hierarchies of co-ordinated habits used by an expert typist. All of these special habits are developed and perfected in a definite manner, the simpler habits being continually modified and reorganized, as practice continues, into higher and more economical habits of which new groupings they become the elemental parts, and into which their identity is gradually merged, while these higher habits or groupings are in turn worked over into yet higher complexes, by processes similar to those that occurred in their own formation.

Throughout the course of this development an elaborate process of "short circuiting," difficult to clearly and briefly describe, was operative. In a general way it consisted of a continuous simplification of the elaborate and circuitous methods used by the beginner. The learner's attention and energies cannot at first be applied to the writing in a direct and economic way. Under the influence of the strong desire to succeed in

the new task there are called up masses of old, familiar and easy associations or forms of activity, most of which are not directly serviceable for the work. From these there is *unconsciously* built up by the double process of elimination, and selection and reorganization, the first elementary associations (letter associations) used, and from these in turn the later higher-order habits. There comes to be, if one may so phrase it, a sort of unconscious struggle for existence among many modes of action ending in the survival of the one direct and economic way of reaching the goal desired. By this simultaneous process of elimination and recombination, the first elaborate and circuitous methods of writing are simplified, refined, changed, until, sheared of all acccessories they enter *into* and *constitute* the most direct and economic method of work within the attainment of the learner. Some of the habits of the early stages seem to exist only to be eliminated, but most of them, as well as the many seemingly useless mental strivings and acts, play an important role in the development of the higher-order habits. They constitute the raw material from which the more direct and economic habits are formed, and are therefore a necessary precondition for their attainment. Those not so used must be regularly discarded as fast as outgrown to keep the learner's progress from being arrested on a lower level of attainment than he is capable of.

All this, if now somewhat vague and obscure, will be made clear in sections "A" and "B" below, where are described in detail the formation and development of the various psychophysical habits (Habits of Manipulation) involved in the mastery of typewriting. The more purely mental habits (Habits of Control) developed in the course of the learning will be treated later in section "C."

A. DESCRIPTIVE ANALYSIS OF LEARNING TO WRITE BY TOUCH.[1]

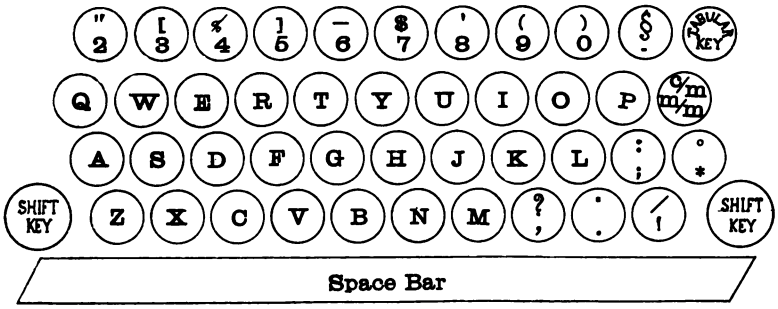
1. The Letter Association Stage.[2]

(a) The Writing in the Earliest Stage. (1) Learning the Keyboard.—The first task of the subject was to learn the keyboard as a preliminary to the formation of an association between the letters in the copy and the corresponding keys of the

[1] In our experiments the learning by the T. M. followed that by the S. M., but as both the writing and learning by the S. M. proved considerably more complex than by the T. M. the latter will be considered first.

[2] In describing the growth of skill in a complicated manipulation

machine. Y[1] learned the keyboard, of which a cut is shown below, by committing it to memory. He learned it so well that he could draw it correctly from visual memory when he began his first test. The thought or inner pronunciation of any letter called up at once a visual image of its exact position on the keyboard. This gave him his cue for finding it with his fingers. "When writing," he says in his early notes, "I have to stop for each letter to recall by visual image where the key wanted is, then make the proper finger movements in the right direction and distance. In making each letter a distinct image of the letter in its exact position on the keyboard comes up to direct my fingers and hand."



X, though a good visualizer, used a different method in learning the keyboard. After a twenty-minute attempt to get a workable visual image of the keyboard (he knew from Y's notes

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like typewriting it is necessary for the sake of clearness to mark off definite stages and to speak of them as though they were distinct and successive, while as a matter of fact this is only relatively true. Let it be understood, then, once for all, that while we shall speak of letter, word, and phrase stages, we are to conceive them not only as passing into one another by imperceptible gradation, but also as not exclusively successive. Certain simple and common phrases are handled as wholes at a time when certain rarely used letters still require individual attention.

[1] The two subjects, X and Y, who learned to write by touch had already learned to write by the S. M., as has been said, but learning the T. M. was so different that they had to begin at the beginning and proceed in the same general manner as the control subjects who were taken through the elementary stages of this method. In what ways learning to write by the S. M. helped X and Y in learning to write by the T. M. the data at hand does not enable us to say. Some helpful associations were surely carried over but no attempt has been made to determine their exact nature. Some of the more general helps (emotional and other) will be considered later (see pp. 74-5, 165-6). This problem might be studied to advantage, it seems, by having a learner who has learned to write well with a "Universal Keyboard," learn to write on a machine with a different arrangement of keys.

the method he had used) he gave up trying to commit it to memory and made an actual map of it instead, which he kept before him in his practice as long as necessary. He at once began to write. If he did not know the location of the letter he would refer to his map moving his fingers to the desired key and striking it while looking at the map. An independent visual image was never used to locate the keys. All that occurred was a movement of attention, in intimate connection with an incipient motor image, to the exact position of the keys, if their position was known (and knowing their location for X consisted in just this), if not, the map was referred to to give attention its cue. A few cases were observed, while this first association was forming, where, when attention could not move promptly to the exact position of the key, a visual image of the letter on the keyboard map came in to give attention its cue, but this was the exception. The visual image, if it appeared at all, came in after attention had moved to the right place on the keyboard and stopped. The visual image was an entirely useless thing so far as locating the keys was concerned.[1]

(2) Locating the Keys.—The next task confronting the learner was to get his fingers to the proper keys. This was in the beginning of the T. M. a very difficult process, especially for all those letters situated near the center of the keyboard. The little fingers had to be kept constantly on the "a" and ";" keys. From these as reference points the key desired was located by the unseen fingers, if its position was known. To reach such a key it was first necessary to locate (by feeling) the row in which it was situated, then find the key itself by touching all the intermediate keys up to the one desired. If, for instance, the "t" was wanted, the learner would go to the row above his

[1] How purely motor this mental location of the keys was in the case of X the following facts will show. At the beginning of the third day's practice, X could locate correctly only six of the nine figures and nine of the letter and punctuation keys from visual memory, and this after 174 days' practice by the S. M. (compare table in note, p. 14). A visual image of the entire machine, the board used to cover the keys, the space bar, the white surfaces and rims of the keys, their zigzag arrangement were clear in visual memory, but the keys could not be located except by a direct movement of attention to the right part of the keyboard, which in reality was merely incipient eye and throat movements distinctly motor in nature, the "left overs" from the former eye movements used to locate the keys in the S. M. Attention of itself moved in the right direction and to the right place. Even the map used to learn the position of the keys could not be correctly visualized at the beginning of the third regular period of practice. Only ten of the thirty-two positions could be located from visual memory. The upper

little finger and with the other three fingers of his left hand feel each key separately, noting as he raised his fingers, *q, w, e, r, t.* This method of literally "feeling his way" to each letter as wanted was the first regular procedure of all the subjects in getting their fingers to the keys. The final step required to make a letter in this earliest stage was a second inner speaking of it necessary to set off the final letter-making movement.

The earliest writing involved, therefore, (1) getting the copy, (2) an actual spelling or thinking of each letter to be made, (3) mentally locating it on the keyboard, (4) getting the proper finger to the key, (5) again pronouncing the letter or initiating the final letter-making movement. The first improvement in the writing was due to "short circuiting" each of these steps. As practice continues each step of the process becomes easier and easier until all fuse into one. When the "short circuiting" is complete so that the sight of the letter in the copy or the first speaking of the letter (the spelling) calls up at once the direct movement for striking the proper key a *letter association* has been formed. How did this "short circuiting" occur or how were direct letter associations developed?

(b) Short Circuiting the Earliest Methods of Writing. (1) Fusion of the First and Second Step.—In the earliest writing the copy was memorized as in the S. M. learning and held in immediate memory until tapped off on the keys. The spelling of the words, i. e. the associations necessary for reading the letters composing them, was of course, something which the learners brought with them to the task and which they did not need to learn. It was a habit ready for use, but even in this most habit-

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left hand corner of the map could not be visualized at all. "When this part is attended to," wrote X, "I immediately get a motor image of the movements required for reaching the keys on this part of the board."

But various sorts of images did accompany the movement of attention, e. g. images of the printed letters, the image of the letter on the map, etc., but in no case did these assist in locating the keys. They came **after** or simply **accompanied** the movement of attention. It was not uncommon for a wrong image to appear, e. g., It was one day observed that in turning attention to the positions of "m" and "n" on the keyboard a visual image of the **printed letters** came up, instead of the image of the key. If a visual image of the letter did come up, it was not always in the right place; "o" was once visualized in the middle of the keyboard.

These two methods of finding the keys come in the end to the same thing, however, a muscular image that soon fuses with the movements required for getting the fingers to the keys. But the association was differently developed by the two learners. In the case of X it was in motor terms from the start. For Y it was first visual-motor then motor.

ual part of the work an important change occurred. The learners unconsciously began to keep their eyes focussed more and more on the copy because of the difficulty occasioned by holding the copy in memory. The spelling became more and more incipient and fugitive until the mere sight of the letter in the copy, which soon came to be closely attended to, set off at once all the processes, psychic and physical, involved in striking that letter on the machine.

To what extent the former actual spelling was replaced by mere visual sensation and yet how easily the learner slips back to earlier methods of working is shown by the following observations and incident. On April 19th, Y wrote: "Getting the copy is now a very easy task and requires only a small portion of the attention. The eyes are kept on the page all the time and I get the letters as a pure sensation. I make the letters and write the words and am not aware as soon as I have finished them that I have seen them. The mere sight of the letter sets off the movement. When for any reason I look away from my copy and come back to it I often start writing at the wrong place and do not notice my mistake for some time."

In one of the practice periods of X at this stage, the paper in the machine was by accident pushed up in such a way as to cover the copy. This caused great confusion and immediate loss of orientation on the keyboard. X found himself actually spelling out the rest of the word he was writing. Several tests were then made at different times to write without keeping the eyes on the copy. These seemed to show that seeing the letters not only helped in mentally locating the keys but that it was an aid to the finger location as well. Fixating the letters in the copy with the eyes had completely taken the place of the former spelling. Any attempt to write from remembered copy at once brought in an actual or incipient spelling.[1] On April 14th, Y wrote: "When I get lost on the keyboard (lose my orientation), I have a strong tendency to look at my writing to get my bearings again. When this is done I generally look ahead and get enough copy to last until I get orientated again on the keyboard. The tendency to spell (vocalize) the letters is in this case noticeably stronger."

[1]Compare the return of inner spelling in the word association stage, p. 37 below.

When letter associations are developed and fixating the letters with the eyes has taken the place of the former spelling, there is no difference, so far as getting the copy is concerned, between long and short words. The spelling occasions no difficulty because no real spelling is done. A Foreign word can be as easily written as an English word. A very strange or long word may call a little extra attention to itself and so, like any distraction, cause slower work on the keyboard, but none of the troubles that come later from uncertain, non-automatic spelling can occur here because the letters are taken directly from the page as a visual sensation.[1]

(2) Fusion of the Third and Fourth Steps.—The third and fourth steps required to make a letter, the dual process of first locating the keys mentally and then finding them with the fingers, went through a still more elaborate process of "short circuiting" as direct letter associations were formed. With practice the thought or sight of the letter in the copy came to call up ever more readily the visual image (for Y) or movement of attention (for X), which served as a guide for the fingers. But though continually changing in character and efficiency to meet better the learner's needs, these earlier ways of mentally locating the keys were very soon outgrown. The visual image which Y used to locate his letters very early began to give way to a higher, more economic form of direction for the fingers and hands. On the fifth day of his practice he wrote: "I have still a general visual image of the keyboard, but the keys are now located by making use of a sort of visual-motor image that tells me more readily and surely the direction and distance of the keys desired." The second and third steps in the work had

[1] In the T. M. learning getting the copy presents no separate problem to the learner. It is gotten as written, in the letter association stage, letter by letter; in the word association stage a syllable or word at a time, in the expert stage it is slowly read as tapped off on the keyboard, but some five or six words ahead of the hands.

In the development of this economic method of getting the copy some characteristic differences occurred between the different learners. Y began by first memorizing several words of copy as in the sight method, then writing them, orientating himself on the keyboard and guiding his hands to the proper keys by watching his writing on the paper. (It will be recalled that the machine was a visible writer). But soon he began to keep his eyes more constantly on the copy and found that this greatly facilitated the writing. Still, the old method of copy getting was so strong that his attention was not, for some time, so economically distributed over the two parts of the work as it came to be later on. On March 13 he wrote: "I find when I write, looking always at the copy, that my attention is on the copy only a small part of the time. It seems to be natural and easy to take in a part of the copy that will

already begun to fuse with the fourth. X, at about the same stage of advancement, described at length how the movement of attention to the exact position of each key came to follow always more naturally and easily upon the sight or spelling of the letters, and the movements necessary for getting the proper fingers to the keys more closely upon this movement of attention.

(3) Abbreviating the Fourth of the Five Steps and Rise of Motor-tactual Image.—As might be inferred from the description of the earliest stage of learning (pp. 24-27), the greatest opportunity for saving was in the fourth of the five steps, in acquiring more economic methods of getting the right finger to the proper key. It marks a long step forward in the learning when the subject acquires the ability of going directly to any key desired merely by attending to the motor-tactual "feel" of that particular letter-making movement. Improvement in learning to make this movement directly is very gradual and slow. At first, as has been said, every letter had to be located by finding its row and then counting one's way to the right key. The keys near the little fingers were the first to be located in this direct manner. If two letters adjacent on the keyboard occurred in succession, "e" and "r" for instance, only the first had to be located from the little finger position. With the proper finger on one of the keys the second could very early in the practice be directly struck. A few direct letter associations were also soon formed by various means and other letters located with reference to them. X, for example, early learned to locate "t" by attending to the feeling of strain required to reach it directly. His general early method, when wanting to strike "e" or "r", was

last some time for writing. My attention for the most part is on the keyboard and finger movements. But keeping my eyes on the copy makes it easier to find the place and go on again at once when I want more copy. The attention shifts back and forth from the copy to the motor-touch image of the movement." Later he unconsciously adopted the letter by letter method of getting the copy. On April 12, when the change was taking place, he writes: "The attention is now mostly on the feel of the fingers, on watching whether or not they are being rightly placed. Much of the time it seems to be divided between this and seeing the copy, instead of alternating between these two. When thus divided I do not run ahead with the copy at all but simply look at the letters I am writing." A few days later, April 19, he wrote: "Only visual recognition seems now to be necessary to set off the individual movements. There is no tendency to vocalize the letters. They are gotten directly from the printed page as a pure sensation."

The fact that X, who, as experimenter, had observed the economic method of getting the copy, unconsciously developed by Y, should use it from the start is suggestive.

first to locate "t" directly, letting the proper finger rest on it, then strike "e" or "r" in relation to it.

In this part of the learning (getting the fingers to the keys) all sorts of temporary helps and devices were used, and shorter and more direct methods of getting the fingers to the keys were constantly *fallen* into. All sorts of connections between the successive letters of words were formed, by the learners, in feeling their way from one letter to another, and many short cuts across the keyboard were made. X observed that he was unconsciously letting the fingers of one hand rest on the letters last struck while working with the other hand. At first the fingers were always raised from the board as soon as a letter had been struck so that each letter had to be located from the little finger position as reference. This new procedure proved helpful because the next letter to be made with that hand could, as a rule, be located more easily from this position than via. the little finger as a point of reference (see p. 96). He also observed that he was remembering the "feel" of the movements when letters recurred at a short interval, so that he could strike a letter directly a second time if the interval since it was last struck was not too great; he often described in his notes how he held the image of such a direct movement in immediate memory and unconsciously learned to attend to it, because it was easier than to locate the letter and make the movement in the old roundabout way. Many other devices were employed in getting the fingers to the separate keys, such as learning to skip across the keyboard in all sorts of ways within the scope of a group of letters to be made by the same hand, e. g. learning to go directly from "i" to "o" and from the "o" to "n" when writing "ion" with the right hand or going from "d" to "e" direct when writing "dear". *But as direct letter associations developed these devices were all slowly discarded,* the one direct movement being more economic than any improvement of the earlier detailed method. *The tendency to use this better method and to strike for a letter directly instead of locating it by the older (and for a time) surer way was very strong in both subjects. They wanted to strike the keys directly long before they were able to do so.*

As time passed the learners came to rely with more justifiable confidence on the motor-tactual image of the direct letter-making movements for guidance and became less and less con-

scious of the keys which lay between their little fingers and the keys to be struck. X developed his motor-tactual image by gradually eliminating the steps used in building it up and paying less and less attention to the keys that lay between his little fingers and the keys wanted. Y very early applied the "method of trial and error." As soon as he dared, he tried to make each letter directly and if wrong corrected himself by referring to the written sheet. In this way he soon developed a direct association for all the letters, and came to rely for guidance and a test of correctness on the motor-tactual image of his movements. X used the intermediate steps as guides until the direct associations were sufficiently developed for these helps to be discarded.

The most important element in this advance was improvement of motor-tactual discrimination or making clear the motor-tactual image for each letter-making movement. In the earliest writing such discrimination was very weak. The learners had to actually raise their fingers after each stroke in order to be able to count their way to the next key. The keys could not be distinguished if the fingers were not separately raised. The learner could not tell by touch alone whether he had his fingers correctly placed or not. After some days practice three fingers could be put down on as many keys and the keys recognized with one stroke of attention. Later a finger could be slowly moved across the keyboard and by close attention to the "feel" of the movement it could be correctly placed on the key desired. Still later the learners could go directly to any key wanted and recognize at once by *"touch"* alone whether or not the finger was rightly placed. Building up direct letter associations in the T. M., might, therefore, be defined as getting the right motor-tactual "feel" for the separate letter-making movements, or learning to attend to the motor-tactual image of the movements and making it guide the fingers.

(c) The Advance from the Letter Association Stage.—If, as soon as a letter is thought of (spelled) or visually attended to in the copy, the right movement for striking the corresponding key is called forth, and if this movement can be directed as made, a *letter association* has been formed; the association needs but to be further perfected to make possible the development of the next higher order of association (word association). When it has become rapid, easy and certain, the next stage has already been entered upon. The individual movement becomes so easy that

less and less attention is required for its execution and attention is free to assume a higher form of direction, making possible the higher method of work.

The process of finally perfecting these simple associations is, however, very gradual and slow; it was necessary to make the direct movement a great many times with attention carefully focussed on its "feel" before it became distinctly easier. At first the movement must be carefully attended to throughout its whole course. As practice continues its motor-tactual image comes to be attended to more and more generally; as the individual movement becomes fused with other letter-making movements in writing words, less and less attention needs to be given to its "feel." But some conscious guidance is required for months after it can be almost automatically made. Long after the subjects thought that these movements were no longer attended to they were often surprised to find that a little attentive direction to the individual movements was still given and required. A half conscious following of the individual movements for the last letters of the words occurred long after these words could be reacted to as a whole and after it was thought that these letters were being taken care of quite automatically. The complete direction of these movements was turned over to the fingers *very gradually* and conscious direction dropped out too gradually to be accurately described.

It was further observed that the motor-tactual "feel" for these letter-making movements was very easily forgotten. For weeks of the earlier practice it was lost over night and had to be built up each day anew. Moreover, it is not a simple motor image that is to be remembered; the hand is rarely in exactly the same position when a letter is made; the motor image is, therefore, not always the same. Much correct practice is required (the freer from mistakes the better) before one is certain of the correctness of his movements, and a still greater amount of careful practice and the development of a higher order of associations is required before the individual movements are perfected and made wholly automatic. A little attention and guidance is required for many months after the letter associations have been well established. *They are indeed perfected only in and through the formation of the word and phrase associations by which they are superseded.*

A few quotations from the notes of Y will illustrate how touch discrimination was actually developed. "When the keyboard was first covered up," he said, "the sensation was one of utter bewilderment. I had to carefully attend to the little finger positions, the only familiar things on the keyboard. When these were lost they had to be found by feeling around the edges of the keyboard and finding the shift keys. From these the 'a' and ';' keys could be located." Later he could go to them directly by feeling the sides of the keyboard and recognize by touching them that he was correct. Later still he could put his little fingers on them directly. Mar. 10 he wrote: "I recognize the keys now more readily by touch; it at once feels right or wrong when I get my fingers placed." Three days later he wrote: "I can now discriminate between finger positions on the keyboard. I can recognize more easily when I get my finger misplaced. I think the main part of my recent improvement is due to just this fact." On Mar. 15, he wrote: "The marked feature of the practice now seems to be the growing ease with which I am coming to recognize the position of my fingers directly through touch. I noticed today for the first time that I recognize errors at once, when made, merely by the feel of the movement and the touch of the key." A few days later he wrote: "It is easier now to keep the little fingers upon the reference keys. I simply notice as soon as they get off and can replace them directly, recognizing by touch that they are right."

An interesting feature of the perfection of letter associations and the transition to the next stage was the way in which the motor-tactual images disappeared from consciousness. The motor-tactual image is needed as a guide for the movements for a short time only, and having served that purpose it soon drops out of consciousness altogether and only reappears when a mistake is made or when for any cause the learner drops down to a lower plane of writing. On April 9, Y wrote: "I now recognize by touch alone as soon as I have made a mistake." April 14 he wrote: "As soon as I get on the wrong row, a very misleading mistake, I notice it at once. When all is going well the feel of the movement does not come into consciousness any more at all."[1] *Failing to recognize the correctness of the individual*

[1] The following observations of Y with their dates will show how gradually attention to the individual movements dropped out. May 1st: "The dropping out of recognition of the separate movements is also pro-

movements when going right is the first step in the automatization and the beginning of the formation of a habit of the next higher order where the syllable or word is made the unit of attention.

(d) Distribution of Attention in the Letter Association Stage.—The attention of the learners in this stage was variously employed according to their grade of advancement. In the earliest writing the whole attention was focussed successively on each of the five steps required to make any letter—first on getting the copy, then on spelling the letter or fixating it in the copy, then on mentally locating the corresponding key on the keyboard, next on the movement required for reaching that key with the proper finger, lastly on the initiation of the final letter-making movement. A number of cases were recorded where the letter was actually forgotten during this process of making it, so much attention had to be given to the separate steps. The last step, initiating the final letter-making movement, was rather easy; the major part of attention was given to guiding the fingers. Gradually, as we have said, the four steps fuse into one continuous process which came to be attended to as a whole, the stress of attention being on the motor-tactual image of the final letter-making movement. As one of the subjects expressed it: "By far the major portion of attention in this stage goes to the feeling of touch and movement. These are more or less constantly watched with respect to their rightness

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gressing quite noticeably. I now write several words sometimes, without getting my attention at all on any of the separate movements." May 9th: "I should guess that I made about half the movements this morning without attention to the individual movements. They go by groups and there is no separate recognition except when one goes wrong. Just how far this is the case is very hard to tell, because introspection on it means attention to them. When I try to recall what I have done it seems as though there is little attention to separate movements." May 11th: "There is a distinctly noticeable improvement now in handling the keyboard. I write connectedly, taking pieces of words, whole words and phrases without attention to individual movements. Distinct recognition for correctness of movement has dropped out very much. Consciousness of correctness or error tends to come in only when an error is made." June 6th: "In introspecting now again on the mental content during the writing I was surprised to see how far removed the writing was from that of attending to individual movements. In attending further to this particular point I noticed only now and then a stroke that was individually directed. In trying to attend to the individual movements purposely I found that they were **altogether too fast** to follow." June 8th: "Writing without attention to the individual movements is so prominent today as to be distinctly the rule. The fingers do it alone and the attention goes to them only in cases of error of any kind which gives a wrong 'feel.'" July 22d: "For the last

or wrongness and I can avoid errors much better by attending strictly to the feel of the fingers and keeping constantly in mind where the fingers are. As soon as I fail to do this my fingers go in the general direction only and miss."

The way in which this motor-tactual image of the letter-making movement is attended to at different stages in the development of the letter association is important. When a letter association first becomes operative the letter-making movement is so difficult that it consumes the entire attention, which is distributed over every part of the movement and follows it guidingly throughout its whole course. Every turning point in its course must be zealously guarded which makes it necessary that the movement be made rather slowly. With practice the direct letter-making movements become easier and easier to make, as we have seen, which means that the movement as a whole does not need any longer to be so carefully directed.

At this point attention naturally tends to drift to outside interests or to be pushed too far ahead in the work. If kept as closely focussed on the work as formerly it goes to the invention of more advantageous methods of work and to the control of larger and larger units as fast as freed from the guidance of the individual movements. If this natural tendency to relaxation at this stage is not successfully met and attention pushed ahead to a higher form of direction as fast as naturally freed from the oversight and guidance of these letter-making movements or if attention is pushed ahead too fast there will be an arrest of progress. The stage where these letter associations are being finally perfected, therefore, is a distinctly "*critical stage*" in the learning.

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several days I have again made a special effort to introspect on just how I did the writing, with the result that I found it harder now than before to say anything at all about it. I was chiefly introspecting on the amount and kind of individual directing of the movements for making the letters there was. From my introspection today I conclude that there is practically none of this and that this is also the reason why it is so hard to observe just how the writing takes place. There is now so little attention on the fingers, the moves enter consciousness so little that in the introspection I am practically trying to find something that is not there. By inference from the rate now I also conclude that there can be but little directing of individual strokes and separate recognition of these strokes as to correctness. The rate is altogether too fast to allow thinking of each movement separately in any terms."

2. The Syllable and Word Association Stage.

(a) Initiating the Movements.—A distinguishing feature of the syllable and word association stage is the clear re-entrance of inner speech. In the letter association stage when the copy was gotten letter by letter, the sequence of movements following immediately the focusing of each letter on the page, no actual spelling was required. Visually fixating the letters in quick succession initiated and controlled the sequence of the movements. When the word or syllable became the unit for attention the copy could not so be gotten, and the movements had to be initiated and controlled by an actual or incipient mental "spelling."[1]

(b) Getting the Copy.—The copy in the word association stage is taken as a syllable or as a word at a time and a little ahead of the hands. Attention as freed from the guidance of the individual movements goes more and more to getting the copy and to the unique mental spelling just mentioned. The copy is not actually learned, for the writers are never aware of the connected meaning of what they are writing. In the very beginning of this stage (April 25th) Y reported as follows: "I get my copy almost entirely by taking one letter at a time as they are being written. The exceptions to this are the easy words and combinations which the fingers take care of as a group. In my actual writing my copy getting is a mixture of these two procedures—taking it letter by letter and easy words as a whole, or (when distracted by something) looking ahead a little to get and hold it as in the visual method of writing." Word associations had already begun to form. Later (June 17), when many word associations had been developed he wrote in his special observation notes: "In trying to get more detailed introspections on just how I proceed with the copy and writing under these general conditions it seems that I am, in a very incipient manner, repeating the copy, perhaps the letters, as I write them. In easy short words I do not think that I incipiently pronounce letters but only words. The tendency to pronounce increases

[1] In the succeeding paragraphs "spelling" is used in a rather loose sense to cover cases in which words are pronounced syllable by syllable or single words pronounced entire, because the psycho-physic function of the inner enunciation is similar in the two cases and the earliest literal spelling pours imperceptibly into the later pronunciation. For further particulars with reference to "spelling" as a means of control in typewriting see pp. 39-45.

with the difficulty of the writing. The grouping that occurs seems to be determined all along by the nature of the copy. An easy word is taken as a whole; a few short easy ones are taken in a connected series. A long difficult word may be broken up into groups of easy, familiar combinations, or in case of extreme difficulty it may be incipiently spelled through letter by letter, and written by attending to each individual movement. This way of spelling words or taking in familiar parts of them as a whole (as only pronouncing the word as a whole, when easy), and the manner of attending to the movements seem to run very closely parallel all the time. I take in a thing on the keyboard just as I take it in in the copy—by letter, by combinations of letters, by words, or groups of short easy words."[1] It may be conjectured, however, that the power of manipulation on the keyboard dictated the manner of getting the copy and not *vice versa.*

The increase of speed itself naturally led to this change. When word associations were sufficiently developed for the movements in certain connections to be made faster than the letters could be focused individually by the eye, the copy had to be gotten further ahead and the succession of movements controlled in some other way. When word associations had approached perfection, the inner spelling or pronunciation gave a sort of specific mental adjustment for the required group of

[1] Later, as more and more word associations were developed and phrase associations had begun to form, a different and less economic method of getting the copy was fallen into by Y. He wrote in his notes: "In the ordinary practice now, where maximum speed is not demanded I find that I do not keep my eyes constantly on the copy. I get my copy largely as in the visual method, read a little ways ahead and then write from memory, but the procedure of learning a bit of copy, writing this, then getting more copy, etc., is not nearly so regular as in the visual method. It is not so much looking away from the page as taking the attention off this part of the work. Something on the keyboard will require special attention, when I cease seeing the copy altogether. Some time back my procedure, as I recall it, was different. I then kept my attention divided between the keyboard and the copy and constantly applied to both. The greater speed now seems to demand a change. Formerly the writing proceeded with attention to the individual movements. I was concerned at any moment of the writing with only a few letters of the copy and a few movements on the keyboard. My attention was sufficient to cover both. In getting copy I did not run far ahead of the writing. It wasn't necessary. The faster writing now makes this necessary, it seems, and other changes going with it, make it possible. I have to take more copy now to keep ahead of the hands, hence the looking ahead."

For Y the most economic method of copy getting for this stage was not found. Instead of pushing attention ahead and manipulating the copy as did the expert (see p. 45), Y was caught by an older habit and fell into an easier and less efficient method than that employed by

movements as a whole, and served to guide the fingers to the proper keys as well as to control the order or sequence of the movements. As Y expressed it: "A word simply means a group of movements which I attend to as a whole. I seem to get beforehand a sort of 'feel' of the whole group which is run through with that sort of conception and direction of attention." That is to say the writing comes to be taken care of wholly by the fingers and this inner pronunciation or spelling.

(c) Abbreviating the Spelling.—That which takes the place of the visual fixation of the letter association stage is at first, for most words, a full mental enunciation of all the letters, but as time passes, it becomes more and more incipient and soon links itself closely with the process of locating the keys and yields to a characteristic pronunciation of the syllable or word as a whole. The spelling now constitutes a sort of mental attitude or preadjustment for the word in question, differing, however, with the stage of development reached. At first it meant a hurried anticipatory following of the whole course of the movements to be made both as to direction and succession. A sort of group "spelling" taking the place of the old detailed thought of each letter. June 15, Y wrote: "I think that attention today was very largely on getting the correct feel of the movements with reference to succession—a general feel of succession and distribution. This is quite different from having attention on making the movements with reference to directing them in the right

X. It is, of course, impossible to observe just when these vital changes occurred in the practice, but the notes clearly show that this way of getting the copy (a survival from the S. M. writing) accompanied the tendency of attention to turn away from the work as a whole and came in at about the beginning of the plateau in Y's learning curve. The fact that his attention was now shifting from one phase of the work to another and went from the difficulties of the writing to outside interests was without doubt an element in the non-improvement indicated by the plateau.

Miss A who copied at the rate of 50 words per minute and therefore belonged at the beginning of the expert stage of writing, got her copy in a way similar to that of Y. She kept her eyes constantly on the copy but her attention was alternately focused on the copy and on the writing. She would read a bit of copy then focus on the writing, putting her whole attention on the mental pronunciation of the words which guided and controlled the movements. When she had almost reached the end of the copy learned her attention would again shift to the copy, the writing being retarded until more copy was learned. There was in this not merely a troublesome shifting of attention, but the extra trouble of holding the copy in mind, a distinctly costlier process than getting it as written. Miss A's method of copy getting was doubtlessly due to the fact that her office work was copying from shorthand notes, which could not be transcribed directly on the typewriter.

direction. For this much the fingers can now be trusted alone. They go in the right direction themselves, and also accurately enough, generally, not to miss. But left to themselves they go too fast, get the order mixed, strike two keys simultaneously, etc. This has to be checked, and to this attention goes, which means attending to the general feel of the order and distribution of the movements." He was still in the stage where a detailed attentive following of the individual movements was required.

Later, as the word and phrase associations became perfected, a higher form of "group spelling," where less and less attention had to be given to this succession of the individual movements, became slowly operative. But it went through many changes and developed more gradually than can be described. The lower and more detailed forms of mental "spelling" proved useful long after it was thought that they had been outgrown. And an actual or incipient spelling of the individual letters persisted and was useful long after it ceased to be consciously attended to. At the close of one of his last practice sentence tests (July 25), when Y's writing was as automatic as it ever got to be, he wrote: "Just for an instant today, when my attention was half directed to it, I found myself, after all, incipiently pronouncing every letter as I wrote for several sentences. I had felt for a long time that no spelling was any more present." In a note written at the close of a regular daily test, June 22, he said: "In the words 'psychological' and 'physiological', it seemed today that the reason why they are hard is the fact that they are not spelled as readily as other words. I have noted often that in these words I look at the individual letters in the copy much more than I do at other times. It is not only writing by letter in these cases but also taking in copy by individual letters."

As a matter of fact in the actual writing at any given time all degrees of "spelling" are to be found, from the lowest kind used in the early stages, to the most habitual and subconscious sort used when the writing is most automatic.

(d) Locating the Keys.—The group method of locating the keys, which in this stage of advancement gave direction to the fingers and which was developed in conjunction with the group spelling just treated, was described by the learners as follows: "There is a change in attitude or what not towards the key-

board," wrote Y May 10, "that seems to go with the increased ability and ease in handling it. I have noticed it for several days but hardly know how to describe it. It is something like getting what might be called a general motor-touch image of the whole keyboard. As I write along easily and pretty fast—this is when I am most aware of this process—I seem to feel beforehand in what direction the following movements are to be made and seem further to have a vague motor knowledge of the positions of all the keys. There goes with this a feeling of satisfaction, confidence, ease and assurance that all the keys can at once be located as needed." On June 6, he said: "The procedure seemed something like this: I first feel for the position of the fingers at the start, and somewhat recognize their position and correctness. With this as a start a group of letters is struck off in quick succession to the end of a word or to a point where, from some cause, a difficulty arises. Then I become aware of where my fingers are, especially of those that are to strike the next keys wanted and those used precedingly. With this is apt to go a slight visualization of the position of the key wanted next and the conscious direction of the fingers to that. It is pronouncing the copy, the recognition of where the fingers are, and the feeling that they are correctly placed, which form the basis for such a group of movements. These groups are, however, of all lengths and succession from one letter to several words." At the close of one of his daily tests at this stage Y wrote: "I make my best speed. I think, when writing by groups, striking off the easy words and groups of letters very fast and then stopping somewhat, for an orientation for the next group. It seems that this anticipatory 'feel' or orientation for a word or group of letters is increasing considerably. I have not been able to analyze it much. I believe in these cases I always start with some sort of initial recognition of the position of my fingers, i. e., my orientation must be gotten at the start. With this much I approach such an easy word with an attitude of confidence. I feel certain that it can be run through with as a group. In writing it I am quite unconscious of the individual letters or strokes; the correctness or wrongness of such a group of movements is recognized as a whole. If an error occurs, I simply recognize that something is wrong but will not know what the error is until I stop to analyze or look at the writing."

After several weeks work on his practice sentence X wrote: "Attention is mostly on a sort of general direction of the movements. There are 'areas' including as much as a whole phrase, in which there is no directing of individual strokes at all. The position of individual keys, here and there, in such 'areas' may be thought of but this is simultaneous with, or an after thought to, the process. It is hard to say what attention is on in these cases. I feel the movements, of course, but am not aware that any particular stroke is right. Another characteristic of the writing in these easy 'areas' is the fact that although there is no recognition of the correctness of individual strokes, an error is sometimes very distinctly recognized immediately. But there are, of course, many errors that are never recognized. These 'areas' are broken up from various causes, the details of which I cannot state."

Another important factor in the development of this group method of locating the keys is the change which occurs in the growth of the motor-tactual image used in directing the fingers (see above, pp. 30-32). As word and phrase associations are perfected the motor-tactual image, which formerly was attached to the individual movements for purposes of guidance, now, in this stage, changes and comes to be attached to the larger groups of movements representing phrases and words, and serves to guide the group of closely associated movements as a whole. All the learners described such an image[1] for the practice sentence as well as for many individual words and phrases. Y, who crowded himself into a breakdown stage in his practice sentence writing (T. M.) described in detail how the correct "feel" of the sentence as a whole had been modified by the mistakes, and how the wrong and unnatural feeling aggravated the trouble.

(e) Distribution of Attention in the Syllable and Word Association Stage.—Attention in this stage is, as we have seen, chiefly given to the mental "spelling" which controls the sequence of the movements and helps guide the fingers. As the individual movements become easier and easier of performance attention advances to a higher form of direction and control, coming at last to manage the group of movements representing a syllable or word, first by a detailed direction of its part mem-

[1] It is psychologically important and significant that all the images which appeared in the different stages of the writing were first prominent and distinct, then hazy and indistinct, disappearing entirely soon after they had served their purpose in the learning.

bers, later by a more general guidance of the group as a whole. Just here a great difficulty is encountered; *it is not easy to keep attention focused on the mental "spelling" and its motor accompaniments long enough to secure perfection in the word groups nor to cause it to assume the higher forms of direction and control as fast as it is set free from the oversight of the details.* Failure may take one or the other of two clearly marked directions. (1) As attention is gradually freed from the oversight of the former details it may desert the writing in a large degree and turn spontaneously to the many irrelevant associations that hover about the threshold of consciousness instead of pushing ahead to a new and better way of writing. *The learner at this stage is apt to be caught by the law of habit and continue the writing on a low plane when he should be forging ahead.* Or (2) the learner unconsciously assumes a freedom and skill which he does not possess, and pushes ahead to a higher form of direction *before* the associations have been made sufficiently automatic for this to be safely done. *The slight conscious direction needed for so long a time to properly perfect the associations is neglected and trouble and arrested development result.* The numerous mistakes in the regular writing at this stage and the "breakdown" in the practice sentence writing are evidence of the reality of this tendency and warrant our referring to this stage as a second "critical stage" in the learning.

3. The Expert Stage.

In the expert stage word and phrase associations have been developed and perfected to such a degree that the writing is absolutely continuous. The word, phrase and clause have become the unit of attention. After describing his practice sentence writing, towards the last of his practice, Y wrote: "When I write several words in succession in this way they run more or less together. The movements no longer are separated into groups according to the words. I am no longer conscious of the words or groups of movements which they represent but have my attention on getting through with the sentence as a whole and on a general control of the successions of movements required to write it." On another day he wrote: "I now write several words without getting my attention at all on any of the separate movements. At the same time I do not seem to be very conscious of making them in groups, a group for a word,

etc. They seem to be more continuous." Still later he wrote: "There seems to be no grouping of the movements according to words or even phrases. There is now no grouping except as caused by particular difficulties. Without such difficulties the smooth running-along of the writing would seem able to go on indefinitely." An association was even formed between the last and first part of this practice sentence so that the repeated writing of the sentence was absolutely continuous on the records, as was the writing of Miss Carrington, the expert (compare Fig. V, p. 88, record, H).

In the regular writing of the latter, words and groups of closely connected words had taken the place of the single letters and were reacted to mentally as wholes, i. e., the sight and pronunciation of the words or the phrase called up at once as a whole a sort of semi-conscious feeling of the necessary movements. This was all the copy meant to this writer. Attention was pushed ahead of the hands as far as possible (usually four or five words), a sort of backward regard being maintained for the general direction of the actual finger movements. The whole course of the movements being held in the span of attention. The advantage of thus getting the copy several words ahead of the hands is that special attention can be given to any difficulties which may arise, for all words and letters are not equally easy even for an expert.[1] Some letter sequences are difficult because the spelling of the words is not automatic. When such words occur in the writing there is a redistribution of attention, but the writing is never checked if attention is working perfectly. The attention span may be shortened as attention is given to the solution of the special difficulties foreseen, but the hands never catch up. Many special problems are thus solved and unusual manipulations of the machine or paper made without any noticeable check on the speed of writing because the copy is gotten so far ahead of the hands. The true expert whose attention is properly trained can go unchecked in her writing until stopped by fatigue.

One of the most serious difficulties encountered in the expert stage is caused by interference of associations. In the formation of word and phrase associations all possible sequences

[1] The words "number," "states," "business," "acquisition," "but," and a few others gave trouble to Miss Carrington, and she could read only a certain distance ahead, the latter varying with the copy, her mental freshness, etc.

of letters and words must be absolutely learned. Until the associations for the words "the" and "this", for example, are both perfect, the writing of the "th" in "the" may end in "is" unless the strokes receive individual attention. The same holds for the syllable, word and phrase associations.[1] The order in which words come in the sentence thus becomes important. An association is soon built up for certain orders of words and whole groups of words when coming in this order can be dashed off with much less attention than other arrangements of the same words. The possibilities of word combinations are, however, enormous, and the formation of perfect associations for all the combinations is impossible. A possibility of interference is therefore never absent and enough attention must always be given to the separate words and phrases to avoid such pitfalls. By keeping from four to five words in mind at once and keeping part of the attention on these separate words the necessary supervision can be given.

(a) Getting the Copy.—The copy in this stage is gotten by reading it a word at a time, but, as has been said, a number of words ahead of the hands. The eyes were kept on the copy continuously. Each word is incipiently pronounced but in a peculiar way. For an easy word the pronunciation was incipient only and free from accents; for a long or difficult word the pronunciation was by syllables variously accented or emphasized. All this was brought out clearly by having the expert read her copy aloud as she wrote it. There was often a pause also after the pronunciation of a word. But this was not a waiting for the fingers to write the word, as they were regularly several words behind; neither did it seem to be a matter of their finishing a group of movements so much as getting a sort of mental adjustment for the word, necessary for its writing, and perhaps also to having reached the limit of the writer's attention span.

(b) Initiating and Directing the Movements.—It was this incipient or actual pronunciation of the words, itself a refined

[1] It should be added that this difficulty is also present in earlier stages of the writing (see p. 70) and disappears as soon as both words or phrases become automatic. When an association for both groups of letters has been perfected there is something about their pronunciation that properly guides and controls the series as a whole. This agrees with the results of Munsterberg and Bair. Compare Munsterberg's Experiments on Association, **Beitrage**, Vol. I, Heft 4, Freiburg, 1892, pp. 1-146; also Bair's Study "The Practice Curve," **Psy. Rev. Mon. Suppl.**, Vol. V, pp. 38-48.

form of the group "spelling", operative in the previous (word association) stage, that now initiated and directed the letter-making movements. The incipient or actual pronunciation of the words somehow directed and controlled the sequence of the letter-making movements. The *former* group spelling and the psycho-physical processes involved in locating the keys in the previous stage have fused into this highest form of "group spelling", the reading of the copy. But the direction given to the letter-making movements as well as the control of their sequence is of a more general nature now. At certain spots in the general writing and during fatigue a more detailed spelling occurred, but even this was more automatically performed in this stage. The pronunciation of the word or phrase starts the series of movements, each succeeding movement being initiated and directed by an unconscious regard for the motor-tactual images of the immediately preceding movements.

(c) Distribution of Attention.—Attention in this stage is, as we have seen, largely on pronouncing the copy, the substitute for the mental "spelling" and locating processes of the previous stage. But a little attention must still go to the control of the hands, keeping track of where they are and urging them forward. A part also goes to a sort of general control of the sequence of the movements. That the order of the movements and initiation of the separate groups is not entirely automatic even at this stage but must be carefully and cautiously guarded at times to prevent mistakes, is certain. The function of attention in anticipating and solving these difficulties has already been mentioned and will be treated fully below where the more general habits formed in reaching this stage are described.

The expert stage is normally not one of relaxation, but quite the opposite. Attention though, perhaps, more habitual is even more completely centered on the work than at any other stage of advancement. Especially is this true when the expert is at her own highest level. In discussing the writing of an international contest Miss Carrington remarked: "If, when I am in a contest, the thought ever flashes through my mind, 'I wonder how my rivals are getting along,' I know I have lost."

The role played by attention in the attainment of this expert stage will be described in section C below. Certain special habits of attention were formed in the course of the practice as important for learning as the development of any of the

special habits of manipulation so far described; for these habits of control see section C below.

B. DESCRIPTIVE ANALYSIS OF LEARNING TO WRITE BY SIGHT.

In the S. M. of typewriting where the letters on the keyboard are located by the eyes three distinct problems confront the learner: (1) Memorizing the copy, which, with the distraction occasioned by the writing, was by no means easy at first; (2) shifting attention from the copy to the keyboard and *vice versa;* and (3) writing what had been memorized. The most expert sight writers among our subjects had not even approached the economic method of getting the copy used by the touch writers. In the semi-expert stage the eyes had still to be used to guide the fingers. In the expert stage the sight writers have reached, but in a more round about way, a method of writing not essentially different from that used by the touch writers. That is to say, to acquire a truly expert skill the habits of the touch writer, towards which the whole learning seems to move, must be acquired. But in the learning some marked differences occur.

In the beginning the sight writers have a great advantage; in the fourfold process[1] of the first writing (spelling or pronouncing each letter of the copy, locating it mentally on the keyboard, getting the fingers to the key, and executing the stroke), sight learners have a distinct advantage in executing the second and third steps. A glance of the eye takes the place of the mental location of the keys, a mechanical touching of the key upon which the eye is fixated, that of the tiresome feeling after an unseen key. But the sight writer has three problems to solve, the touch writer but one. In the T. M. writing getting the copy presents no separate task or difficulty. The working psychosis is uniform. In the S. M. the copy must be learned and somehow held in mind until written. This involves not only extra labor but a troublesome shifting of attention and a mental re-adjustment each time the writer turns from the business of copy getting to the manipulation of the keyboard and *vice versa.* This together with the fact that the associations to be

[1] In the Sight Method where the copy is memorized, getting the copy becomes a separate problem for the learner as we have seen, so that in the earliest writing by this method there are four steps instead of five as in the T. M. learning (compare p. 27).

formed are not developed in the most economic way makes learning by the S. M. much less economic than by the T. M.

We shall be chiefly concerned in this section with two of the four steps involved in the earliest writing, the first, pronouncing each letter, which presupposes learning the copy, and the second and third taken together, locating the keys. The final step, striking the keys, was doubtless, like the others, changed by practice, but on this point we have no special data.

1. Getting the Copy.

From the objective records it was found that skill in taking the copy increased almost *pari passu* with the increase of skill in writing. At all stages memorizing the copy took in round numbers about a fifth of the total time. During his first test X spent 185.5 seconds out of a total of ten minutes in learning his copy; in his fifth test he still spent 165.75 seconds. By the tenth day he had, however, decreased the amount of time spent in learning the copy to 96.25 seconds. After he had been writing a month he still spent an average of 115.4 seconds a day (average for 10 days, M. V. 5.677) and during the last ten days of his practice, after he had been working for 164 days, he spent an average of 125.85 seconds a day (M. V. 9.21) though of course the actual amount of copy now learned was nearly six times as great as during the first days of practice. Z, during the first 10 days of his practice, spent on an average 129.4 seconds (M. V. 11.7) out of the regular 10 minutes of the test in learning his copy. After 70 days practice he still spent, for the next 10 days, 123.6 seconds per day on memorizing his copy (M. V. 4.44). For both learners skill in taking the copy increased, therefore, relatively, a little more rapidly than skill in writing it.[1]

While the relative gain is thus small, the absolute gain per word is considerable. The first day X wrote he spent on an average 2.13 seconds in learning each word he wrote. By the fifth day he had cut this down to 1.34, and by the 15th day to 0.58 seconds per word. From this time on improvement was very gradual. During the last 10 days of his practice, after 164 days, the average time spent in learning each word was still 0.47 seconds (M. V. .04756). The average time spent by Z on each word of the copy was for the first 10 days of practice 1.25

[1] This must not be understood to be a gain in immediate memory. Some of the gain is due to the fact that, because of the increased skill in writing, the copy had to be retained a shorter time.

seconds (M. V. .30); and for the last 10 days of practice, when writing at almost the identical rate of speed attained by X after 164 days of practice, was .50 seconds (M. V. .025).[1]

The amount of copy taken at a time and the amount of time spent in learning each word varied with the same learner on different days. On Feb. 20th, X spent 88 seconds in learning a copy of 205 words, an average of 0.43 seconds per word. Three days before it took him 138.75 seconds to learn 184 words or .75 seconds per word. On Feb. 20th he remembered on an average 7.89 words each time he looked at the copy. Three days before only 4.97. After six months practice he spent 109.5 seconds on a copy of 283 words. Two days before he had to spend 141 seconds in learning 286 words, an average of .35 seconds per word for the former and .53 seconds for the latter. The other subjects showed variations equally great.

One of the results of practice was to reduce this irregularity. The subjects learned to reckon with the fact that their ability to deal with the copy problem varied from moment to moment and from day to day and gradually developed a way of successfully meeting the difficulty caused by these variations in ability to hold the copy. This was shown in a striking way by the decline of the mean variation. Taken for the whole period of practice and calculated for periods of ten days, the mean variation shows almost a regular decrease as the practice goes on, for both the amount of time spent in getting the copy and for the

[1] The notable difference seen in the amount of time spent by X and Z in learning the copy in the first few tests is probably due to different methods of learning it. X was of a mixed visual-motor type and learned his copy by incipiently reading it. It was never actually pronounced but a bodily motor sanction generally accompanied or followed the course of the eyes in reading. On off days and at times of great difficulty there was a distinct nodding of the head and swinging of the body and a more distinct motorization back in the throat for the difficult words. The motorization was noticeably stronger in the early stages of practice and gradually disappeared with the increase of skill. Z was of the auditory-motor memory type and got his copy by motorizing it as he read it. In the early stages of practice this motorization was so prominent that the experimenter could understand every word of the copy he was learning. With increased skill this motorization became less and less apparent. Accessory bodily movements and strong motorization went together. When the work was so hard that Z used every muscle of his body to help him write, the motorization was strongest. It also varied in degree from day to day and during a test, becoming weak or strong according as the difficulties lessened or increased. Z's more complete motorization of the copy seems to have helped him in learning his copy in the early stages of his practice.

average time spent in learning each word, indicating the decrease of irregularity in this part of the work.[1]

The objective records further showed that the memory span of the beginner is very narrow. He writes as a rule less than two words before he must again look at the copy. If the copy is made up of short simple words like "is", "the", etc., he can hold as many as two or three words at a time. When the copy is difficult and the letters hard to find on the keyboard he can remember but a part of a word at a time or at most a single word. There were many cases in the first practices where the word was forgotten in the very act of writing it. The average number of words remembered after each look at the copy was on the first day, for X, 1.88; for Z, 1.39. Z spent 5.07 times as much time per word in learning his copy the first day he wrote as he did on the day showing his highest score, and remembered four and one-half times as many words each time he looked at the copy.

A certain skill in getting the copy is soon developed, however; on his seventh day's practice X held an average of 4.09 words for each glance at the copy; in nine days Z was doing as well. After this the average number of words that could be held with one reading increased but slowly and showed great variation from day to day. On the last 10 days of his practice Z remembered but 5.60 words each time he looked at his copy (M. V. .2492), after 164 days of practice X remembered but 5.26 (M. V. .370). One effect of practice was that the subjects learned how much copy they could successfully hold and how to divide it more economically, i. e., the irregularity in the length of the bits of copy held was much reduced. It was also soon forced on the attention of the writers that when the copy was not firmly held the writing was not only more difficult, but more unpleasant. Any difficulty in recalling the copy caused trouble on the keyboard and any difficulty on the keyboard made the copy slip out of mind. Consequently the habit of stopping when one had as much copy as he felt he could surely carry was unconsciously fallen into by Z and purposely adopted by X, a factor which counteracted the strong natural tendency to overstep one's attention span.[2]

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[1] It is perhaps significant that this irregularity was again increased during the periods of practice represented by both of X's plateaus.

[2] The writer was materially influenced by his study of the drum records of his writing which had shown him the rapid gain he was

A process of refreshing the copy sometimes took place during the writing, whenever the copy tended to slip out of mind. But this was rarely necessary for the copy was either totally forgotten or firmly held in mind. Both learners observed that whenever such refreshing occurred, the writing was always retarded, and in the earlier stages, completely blocked. In the later stages attempts to recall the copy seemed to interfere but little with the writing.

We have used the phrase "forgotten or held in mind" but according to the observations of the learners the copy was not really held in mind, but recalled word by word as needed. As Z described it: "The copy is held in *motor* memory. In writing, it unravels just as it was learned. I never remember it as a whole. Only the word I am writing is present in consciousness. This word, as it is finished, calls up the next, that the next and so on. The moment I attend to the copy by way of refreshing it, etc., a mistake in the writing is sure to occur and I forget the copy. If the copy is even slightly attended to my writing is retarded."

In a later stage the meaning came in both to help and to interfere with the work. In the earlier stages of practice finding and striking the keys was such an all-absorbing problem that the meaning of what was written was but little regarded. Later it began to play an important role for memory and recall. Not only the meaning of the copy but the general style of the author transcribed, affected the facility of the movements. The meaning served as a hindrance in two ways. (1) Previous associations called up the wrong word, the order of a series of adjectives was often changed and the learner inclined to alter the wording of the copy, substituting words of his own for those of the author without being aware of it. The words changed always conveyed the general sense of what was written showing that it was the thought, not the words that was held. (2) If a passage was unusual or obscure, it had a tendency to retard or actually block the work. Any grammatical mistake or hard, unusual construction always checked the progress of the writing.

making in this part of the work. He became interested in the gain he was making by increasing his immediate memory span and began to make a special effort to carry longer and longer bits of copy until he clearly overstepped his limits. Hence his conscious adoption of the method of Z. Z was also prone to overstep his ability in holding copy at first. But he soon unconsciously learned to deal successfully with this phase of the work.

As still more skill was acquired more attention could be given to the meaning of the copy. In the last stages of practice it was not an uncommon observation for the learners to catch themselves speculating about the meaning of what was copied, criticising it, perhaps carrying on an elaborate discussion with themselves as to its value or significance. How much the writing was interfered with by these speculations it is impossible to say. That it made the writing slower and caused it to be done on a lower plane than was possible at the time is certain.

The specific kind and amount of *help* given by the meaning and style could not be determined from our data. The evidence gathered on this point from the learners' notes was sufficiently strong and pointed, however, to force the conviction that Bryan and Harter's belief in Specific Grammatical habits *(Psy. Rev.,* Vol. VI, pp. 363-367), was well founded. An author's general style as well as the meaning of what is written certainly serves both to facilitate and retard the writing by making the copy easier or harder to get and hold, as well as easier and harder to write.

2. *The Shifting of Attention.*

In the S. M. writing two distinct psychoses are required, one for learning the copy another for writing, and the change from copy getting to the writing and *vice versa* caused the beginners not a little difficulty. A complete mental readjustment had to be made each time a change in the work occurred. That such a readjustment was required is suggested by the fact that all learners disliked so much to make the change, which had the same effect on the writing as a bad mistake or serious distraction. Moreover, the drum records showed that the first letters and words of a new bit of copy were written much more slowly than the middle or last words. As Z expressed it: "Learning more copy makes me lose my run on the keyboard. It always takes a little time to get back into the easy flow of the writing movements after a bit of copy has been learned." "Almost as soon as one is well adjusted to the writing," wrote X, "he must stop to get more copy, a distinctly troublesome and disgusting feature of the work."

To get some indication of the loss occasioned by this necessary readjustment and to find out more about what this loss meant psychologically, the following tests were made. Three

subjects were each given six tests in copying and six tests in writing from dictation and the results compared. On one day the dictation test was given first, immediately followed by the copying test, on the following day, the copying and then the dictation test. All the writing was from the same article in the *American Journal.* The results of these tests showed that the subjects could write on an average about a third more from dictation than they could from copy. From the records taken of their regular writing at this stage of skill it was found that each subject, when writing from copy, spent on an average about one-fifth of the total time of any test in learning his copy. Subtracting the actual time consumed in learning the copy from the average gain as shown by the dictation tests we get in round numbers 2-15, a rough indication in terms of time of the amount of distraction caused by the necessary readjustments to the keyboard. In reality the amount is much greater for the dictation in our tests was very faulty, the writer frequently having to stop to wait for more copy, or even to call for it, which interrupted the flow of attention almost as much as the natural alternation in copying. If the dictation had been perfect or if the same amount of practice had been had in writing from dictation as in writing from copy the percentage of saving would have been much greater.

The introspections of the learners showed that in the dictation tests the attention could be more easily and uniformly held on the work. One of the subjects often failed to respond to the bell at the end of the line, continuing to write until stopped by the machine. In all his writing from copy this never occurred. Another subject reported that it was much easier to keep attention where it belonged when the copy was dictated; his attention could be held he thought, more uniformly to the task of ordering and directing the movements. This had the effect of setting the movements on hair triggers, as it were, accounting for their increased facility. A third subject observed that it was the mental adjustment, made in advance to the letters and words, that was broken up and interfered with each time attention was turned from the keyboard to the copy and *vice versa.* As he expressed it: "When adjusted to the writing, individual letters can be more easily located and struck, attention more economically used and the movements better joined together in series."

With practice and increase of skill the difficulty occasioned by this shifting of attention slowly disappeared. In the most advanced stages of practice the readjustment gave little or no trouble at all, the learners turning from one phase of the work to another as easily as a railroad president or manager of a large department store turns from one part of his business to another (compare this study pp. 69-70).

3. *Learning to Write.*

(a) Letter Association Stage. (1) Finding the Keys.—As in learning to write by touch an essential part of the earliest learning was learning the keyboard or forming an association between the actual or incipient pronunciation of the letters and their exact position on the keyboard. Z learned the keyboard perfectly by means of a sort of spatial mnemonic,[1] in the five or ten minutes he was being shown how to manipulate the machine and given instruction concerning his part in the experiment. At the close of his first half hour's test he could draw the whole keyboard perfectly from visual memory. In all his writing for the first few days the spelling or pronouncing of the letters called up a visual image of the letter wanted in its exact position on the keyboard; this served as a necessary cue for the hands and eyes in locating the keys.

X learned the location of the letters on the keyboard in a different and much more laborious way. If the position of a letter was not known—and in the beginning the exact position of none of the letters was known—there was an aimless wandering about over the keyboard in search of it. This happened for all the letters until an association was perfected between the inner spelling and the corresponding eye movements or movement of attention required to locate the keys. A motor image of the required eye movements or movement of attention served as a necessary cue for X's eyes and hands in all his early writing. At the close of his sixth regular round of practice only 20 out of a total of 42 keys could be located from visual memory. An

[1] While the experimenter was adjusting the apparatus and showing him how to run the machine he mentally divided the keyboard vertically into two equal parts, the dividing line cutting the keyboard between the **t** and **y**, **g** and **h**, and **b** and **n** keys. Certain letters were then, by means of temporary associations, located definitely on each half of the board. These letters were fixed in memory by remembering that they went either with the right or left hand. All the letters for the right hand were located with reference to the "p", "m", and "n", those for the left hand with reference to the "a" and "t".

attempt was made to draw the keyboard from visual memory each day after this but it was not until four days later, the tenth day of his practice, that a complete map of the keyboard could be drawn from visual memory. The fact that the visual image of the keyboard began to get hazy and dropped out of memory soon after this, and that all keys could be readily found by the eyes before this visual image of the keyboard was developed, are proofs that in X's case the cue for locating the keys with the eyes was given by something besides a visual image of the keyboard as was the case with Z. X's visual image was doubtless developed by his effort to draw the keyboard each day after the test.[1]

The mental location of the keys (the visual image for Z, movement of attention for X) serves, as has been said, to guide the eyes to the keys. In the earliest writing each key had to be separately fixated by the eyes, a second actual spelling being required to initiate the letter-making movements. The word must be spelled twice, first to start the locating process, again before or as the keys are struck. As X expressed it: "I have to spell out the words in a whisper as I write them. The movement does not follow the thinking or focusing of the letters but the saying of them." The final step required to make a letter, initiating the letter-making movement, gave special trouble for a time. "It takes intense effort on my part," wrote Z in his earlier notes, "to bring about the wished for co-ordinations." In fact the strain is so great that a beginner literally works his whole body when trying to write (compare p. 74). After his fifth day's practice X wrote: "The improvement today seemed to be due to the fact that less volitional effort was required to make the individual letters." "The letter-making movements can not be hurried. It takes just so much time," wrote Z, "to make the necssary co-ordinations and movements."

(2) The First Improvement.—Improvement in the early part of the S. M. writing is brought about, as in the T. M., by

[1] An incident observed accidently by X and afterwards verified, shows that the eyes were not directed by a visual image of the keys. One morning before getting up X observed that he was thinking of his problem and actually going through with a sort of mental writing in which the keys were always first located by a movement of attention to the exact location of the keys. The visual image which was prominent in this play writing in every case came in **after** attention had moved in the right direction and distance and stopped, i. e. after the incipient eye-movement or motor memory image had been carefully attended to.

"short circuiting" each part of this process. Instead of the spelling calling up a visual image of each letter in its exact position on the keyboard (Z) or a movement of attention to its exact location (X), followed by a fixation of that key by the eyes, a second spelling initiating the final movement for making the letter, each step in the process grows easier and easier until the four become one in consciousness. The first spelling or pronunciation of a letter calls up always more easily and quickly its location on the keyboard, a process which very soon fuses with the movements of the eyes required to locate the keys. The eyes in turn become more and more proficient in fixating the different keys. They come to move in a more definite and economical way, making the focusing of each individual letter easier. The individual finger movements that follow the fixation of the keys likewise become easier, while the spelling required to set off the stroke becomes more and more incipient until the four steps can be taken as one.

(3) Distribution of Attention in the Letter Association Stage.—Attention in the first part of this stage is focused successively on the separate steps required to make each letter—the pronouncing of the letter, thinking the position of the proper key, looking at the key, the second spelling or initiation of the movement. Later, attention is on the process treated as a whole. The impulse for striking the keys comes to follow the eyes so closely that the whole writing attention is given to getting the eyes from one key to another as rapidly as possible and to the mental spelling which drives and directs the eyes.

(b) Syllable and Word Association Stage.[1]—When a syllable or word association has been formed, each key is no longer separately located by the eyes, and the letters actually or incipiently pronounced as the separate keys are struck. Only the first letter of that syllable or word needs to be definitely fixated by the eyes. This gets the hands in position and gives the writer his bearings; the further "spelling" or pronunciation of the word calls up at once the conscious "set" necessary for running through the whole

[1] In the analysis of this and the expert stage we are not limited to the records and notes of the general practice of our regular learners, X and Z. We have data from professional subjects and from the work with the practice sentence for three subjects. The latter, before the practice stopped, could write the practice sentence at a rate of more than a hundred words per minute.

series of movements; or if the word association is fully developed, each movement calls up its successor quite automatically.

(1) Short Circuiting the Spelling.—When we inquire into the changes that make possible the handling of these larger wholes, we find a little of the gain due to improved methods of getting the copy but more to the changed character of the "spelling" which resembles closely that already described in the T. M. learning. The condition is pictured concretely in the following notes from the observations of Y on writing his (S. M.) practice sentence. When word associations had begun to develop in earnest, he wrote: "Some sort of spelling is still present I think. When I try to introspect on this point while writing it is distinctly there. But when I do not think about it until afterwards I cannot be sure that I am spelling the words." Two weeks later he wrote: "In writing the whole sentence without attention to whether I am spelling or not I am hardly aware that I do any sort of spelling at all. Occasionally when there is a hitch I find myself spelling. When I attend to it while writing I find that there is no actual tongue movement; holding the tongue tight between the teeth does not seem to interfere at all with the kind of spelling that is now going on. Yet, in this case, there seems to be some sort of vocal following of the letters. I infer that it is incipient spelling, in which the actual vocal movements are absent, as a rule, but occur when there is difficulty or a hitch. In taking one word alone and writing it a number of times in succession the motorization in spelling at once drops out entirely. I then notice no trace of spelling even when I attend to it. The whole matter then becomes a 'bundle' of finger movements that take care of themselves, plus visual elements described below. As the spelling is thus dropping out I find a very marked tendency to get the order of the movements wrong. I frequently get two successive letters interchanged in position. But more often strike two or three keys simultaneously. When I try to avoid this I find myself returning to my incipient, or even actual spelling which at once corrects the difficulty."

Ten days later, January 24, he wrote: "I am certain that I do not spell any of the words. very seldom pronounce them. Even when there is a hitch the tendency to spell is not very strong. I believe that most of the time I am not thinking at all of what I am writing. I have observed numerous instances

when I was thinking of something else while writing, and found myself surprised when I turned my attention again to the sentence to find 'where I was at'. The following were written at about the usual rate, somewhat slower, while singing a note of a familiar tune, i. e., holding it:

Pack my box with five doen liau or jugs.
Pack my box with five doen liau r ufs.
Pack my box with five doenli ur jugs.
Pack my box with five doen lizour jugs.
Pack my box with five doen liauor jugs.
Pack my box with five doen liau rjus.
Pack my box with five doen liaur jufs.
Pack my box with five doen liau jus.
Pack my box with five dozen liquor jugs.
Pack my box withfive doz n liauor jugs.

"I am fairly certain that most of the increased difficulty of writing under these conditions is due to the distraction caused by the novel procedure, the attention goes somewhat to the singing. The cutting out of the spelling or pronunciation of the words as they are written by this device seems to give no trouble at all." This, however, takes us into the expert stage. Y at this time was writing this sentence at an average rate of ninety words per minute. The greatest speed he ever attained was but a little more than a hundred.

The spelling drops out for the last parts of the syllables and words first. "At first," wrote X, January 10, "I spelled the whole word. Now I pronounce only certain letters, usually those at the beginning of the word. With this a whole series of letters, sometimes including two or three words, can be made without focusing or pronouncing the separate letters." On January 18, he wrote: "In smooth, rapid writing I am hardly aware of any motorization at all. In case of a balk I spell the next letter or two. When for some cause the movement is interfered with and comes less easily than at my best stages I can detect a faint motorization for all the letters made during the slow writing. When the highest speed is resumed this motorization promptly drops out for most of the letters. In this rapid writing, one motorization for the entire word is sufficient and all that is given. But only in the smoothest and most rapid writing does this occur. Much of the time a sort of incipient spelling takes place for all the letters. The last letters of a word become unconscious first." At a somewhat earlier stage, while describing the spelling of a certain word, Z said: "I notice that I no longer spell it, but that there are two distinct motor

innervations, one before the first letter of each of these parts of the word is struck."

Both Z and X, who showed a distinct tendency to break up the writing of the practice sentence into groups, more or less rhythmic, often observed that the movements for making the last letters of such a group of closely associated letters were faster than those for the first letters of the group. This observation the drum records for almost any day bear out. Some sort of mental adjustment or general preparation for the whole group is made before the writing starts. Probably the most important element in this is getting one's bearing on the keyboard. In the case of letters hard to strike or in a difficult sequence the "spelling" takes more attention. Some words can never be easily or quickly made because of the course the fingers must take to strike them. These continue to be spelled.

The important and distinctive feature about this change in the spelling is its slowness. The spelling drops out more slowly than appears from these notes or than can be clearly described, a fact which has important bearings on the explanation of the learning curves and the cause of plateaus.

(2) Abbreviating the Early Methods of Locating the Keys. —The "short circuiting" in the matter of locating the keys is even more marked than the changes in spelling just considered. Throughout the letter association stage, as we have seen, each key had to be separately fixated by the eyes. With practice these eye-movements became easier and easier for certain groups of letters and words. As Z expressed it: "I can now use my eyes to better advantage than ever before. I can look quicker and at the same time make a glance count for more than I could." But this is not all. The finger movements soon become so fast that all the keys cannot be fixated individually. As syllable and word associations develop the amount of visual direction required to locate the keys becomes less and less. Finally some of the letters in the words are not fixated by the eyes at all and in the end are not even seen indirectly.

When all the word associations for his practice sentence writing (S. M.) were well developed, Y wrote in his notes: "As the practice continues there seems to be less and less looking at the separate keys. In writing the sentence through about all that now seems to be required is that I have my eye *somewhere* on the keyboard. If I do this my fingers can find most of the

keys as required, even when they are so far from the fixation point that the keys struck in indirect vision cannot be seen as individual keys, and nothing of the letter on the key can be recognized. In fact, I do not seem to make use of indirect vision at all in this case, the fingers can measure off correctly the direction and distance readily enough, when a starting point is given by a visual fixation point. The following were written, one word at a time, with the eyes closed, except that for each word the first letter was first visually located on the board, and the hands put into position; the eyes were then quickly closed and the word written rapidly, as fast as in the ordinary practice:

Pack my box with five dozen liquor jugs.
Pacm my box with five dozen liwi jugs.
Pacm my box with five dozeb liquor jugs.
Pacm my box with five dozen lkquto jugs.

"This speed seems to be quite necessary in order to get it correct when the eyes are closed. If I go slowly I lose myself at once; the 'feel' of the movements as a group is lost and I find myself trying to locate the keys wanted with the aid of my visual map of the keyboard, which is entirely inadequate (he could at this time locate only five keys from visual memory), and I finger along the edges, trying to get my bearings on a visual map. This one thing, giving the finger movements a starting point on the keyboard, seems to be now by far the most important thing that looking at the keys contributes to the writing. If the key for one letter in the word is seen the other keys are struck more or less readily. The whole thing, as far as seeing and noticing keys visually is concerned, seems decidedly easier." A few days later he wrote in his notes: "I am not at all conscious now of trying to visually find the keys as required. I am aware that I move my eyes about some, but they are not consciously directed, and it is only occasionally that I am aware of directly looking at a letter. When I do this that letter is often, if not always, a starting point from which, or a center around which, the movements are grouped. These letters are apt to be the same each time I write the sentence. Instances are the 'd', which I very frequently see before I come to the word 'dozen'; same for 'f' in 'five', and of 'x' in 'box'. It is clear that many of the letters I do not see at all, consciously, e. g., 'o' in 'box', 'h' in 'with', 'z' in 'dozen'. The tendency not to turn the eyes directly towards the keys in the margin of the keyboard, e. g., 'q' in 'liquor', but to note such letters in

indirect vision and keep the eyes more on the middle of the board is very strong. I believe the matter of looking around, i. e., finding keys visually, has become habitual, so that the fingers need much less than before the help of the eyes to find the keys."

This remark is based in part on the fact that writing the sentence a number of times, keeping the eyes focused on the "g", showed no more mistakes than did his regular tests.[1] Later when phrase associations had developed sufficiently, for the sentence to be written as a whole he wrote: "I am now quite aware that visual direction is playing a constantly decreasing role in the writing. I am never conscious any more of voluntarily looking for a key to find it to strike. There are now large numbers of keys, perhaps a fourth, that I do not see at all not even in indirect vision, but I strike them correctly and quite readily. I tried again today to determine what letters I looked at for each word and which ones I struck without seeing, but I found that it did not seem to make much difference which one I looked at directly. One seemed to do as well as another. My eyes move around over the keyboard considerably but since I never move them consciously I infer that the eye movements have themselves become habitual after the same manner as the finger movements."

The observations of both X and Z confirmed these observations of Y. The same letters were not always seen. Only a very general direction needs to be given by the eyes in this stage, vision serving more to get the hands into position and to start the series of movements than for anything else. Keeping the eyes on the keyboard also increased the writer's confidence and was, therefore, of considerable aid. But all that is actually

[1] He adds still further in his notes: "Writing the sentence a word at a time is a much slower and more difficult process. The words of the sentence seem to have blended into larger groups. Writing the sentence a word at a time breaks up these larger groups and makes me lose the 'feel' of the sentence as a whole."

A few days later in his special practice, he wrote his practice sentence (Pack my box with five dozen liquor jugs) a large number of times for the purpose of observing which letters he was still looking at. "Of the following," he said, "I am quite certain. In 'Pack' I look at 'p' and sometimes at 'a', seldom at 'c' or 'k'. In writing 'my' I look at 'y', never at 'm'. In 'box', I attend to 'b' in indirect vision, look at 'x', never think of 'o'. In 'with', I nearly always look at 'w', often but not always at 't', seldom at 'i', and never think of 'h'. In 'five' I look at 'f', sometimes at 'e', never think of 'i', or 'v'. 'Dozen', look at 'd', sometimes at 'e', am conscious of 'z', but never see it, never think of 'o', or of 'n'. 'Liquor', look at 'l', 'i', 'u' and generally at 'r', never at 'q' or 'o'. 'Jugs', look at 'j', 'g' and 's', never at 'u'."

required on the visual side to locate the keys is fixating the first letter of the group. The rest can be located without the direct help of the eyes and for the most part with little help from consciousness.

A fact of far reaching practical significance for the learning is that this visual direction given to the fingers dropped out so gradually. It was found that a little help from the eyes was needed for months after the fingers could almost be guided by the motor-tactual image of the movements. In other words, the keys had to be half consciously located by the eyes for a very long time after they could almost be made by the fingers alone. On a certain day X wrote: "Visual location is now used less and less but I must still half consciously see the keys. I noticed today that a letter I thought the fingers were taking care of completely, was still indirectly located by the eyes." In one of his notes Y wrote: "When I am careful enough not to make a mistake and can turn my attention about quickly enough after I stop writing to see what I was doing I find that I am still indirectly locating most of the letters with the eyes. It is strongest at the beginning of words and for those letters involving a jump on the keyboard. These must still be focused by the eyes." The importance of this fact for learning and its bearing on the learning curves will be later pointed out.

An interesting question is suggested in this connection by the following facts: (1) No case was observed where the "feel" of the movement was consciously attended to for the purpose of guiding the fingers. (2) The growth of the above mentioned motor-tactual associations was extremely slow and gradual, slower than in the T. M. Was the growth of the motor-tactual associations unnoticed because it was so slow as to escape attention; or was the growth slow because it took place without the spur of conscious purpose; or did both causes co-operate to bring about a joint result? Until the general relation of consciousness to learning has been further worked out the last is perhaps the safest assumption (see pp. 95-97, below).

It is certain that the formation of these position associations was slower in our S. M. experiments than in the T. M. learning, but we do not know how much we must allow for the fact that in the case of both our touch learners there was already a basis of motor tendency (probably a considerable one) remaining over, to say nothing about the more systematic fingering

used in the T. M. Whether any importance is to be attached to the further fact that in the T. M. learning the motor-tactual sensations were shielded much more from the competition of the usually more dominant visual sensations than they were in the S. M. learning, can, under the circumstances, hardly be conjectured.

(3) Distribution of Attention in the Syllable and Word Association Stage.—Attention, which, when the syllable and word associations begin to develop, is mainly focused on locating the keys or getting the eyes rapidly over the keyboard, came finally, as this visual direction dropped out, to be focused chiefly on the process of controlling the order and sequence of the letter-making movements, the mental "group spelling." The stage of writing where word associations are being thus slowly and finally perfected, here as in the T. M., is a very "critical stage" in the learning. The learner's attention is apt to go astray and in the same two ways as in the T. M. (see p. 43). The learner tries too much for speed, as X expresses it: "Attention goes to making the movements go fast instead of making *well directed* movements as fast as possible," or he gets lax and lets his attention wander away to outside interests as fast as released from the details of the writing.

(c) The Expert Stage.—When practice has continued until a sentence or group of closely associated words can be dealt with as a whole the learners, as in the T. M., have reached the expert stage. This advance is made possible by forming associations for sequences of words and strengthening the word associations already existing. Locating the first letter of such a group with the eye or pronouncing the words is now about all that is consciously done and needed for writing. In the "practice sentence" the associations between the words became so strong that almost no pronunciation or conscious following of the movements for the words could be detected. "I am now hardly conscious of the sentence at all while writing," wrote X in his special notes for this stage. "Only occasionally am I aware of the word I am writing, which, when I try to think of it, seems to be as much suggested by seeing the keys as by pronouncing the word. I am sure that there is no longer any real pronunciation of the words and no trace of spelling of any sort. The sentence merely means a group or series of movements and the 'feeling' of these move-

ments is the uppermost thing in consciousness. When they go easily and in the proper succession I am conscious of this fact. When they are difficult and go wrong I am also keenly aware of the mistake. Finding the keys is no longer an element. Errors are made not because I miss the keys or fail to properly locate them, but because I strike them simultaneously."

(1) Short Circuiting the Spelling.—As in the previous, word-association stage, controlling the order and sequence of the movements is now by far the most important part of the process. "During the past ten days or so," wrote Y in his practice sentence notes, "I have noticed a great tendency to get the finger movements mixed up. With maximum effort, especially, I would often strike two or more keys simultaneously or in wrong succession. The tendency was for the fingers to go on by themselves and I found in many cases when an error was made and recognized that it would take special attention and effort to stop my fingers; of themselves they would go on to strike the next keys. It seemed as though the finger movements were too fast to be all followed by attention, and yet required that attention to guide them. To prevent the numerous errors that were made in this way I finally began to check my finger movements and to attend particularly to making them go in the right order. I put it this way because it was distinctly this, rather than looking more at the keys. I do not think that the visual location of the keys came in more at all in trying to prevent these errors. It was a matter of getting the correct 'feel' of the succession of finger movements, and to this the attention went.[1]

That the old time spelling was finally completely superceded by some other method of controlling the sequence of the movements, is shown by all the observations made at this stage of development. "There is now no noticeable trace of spelling going on while writing," wrote Y; "the following were written at about the usual maximum rate while humming a familiar tune:

Pack my box with five dozen liquor jugs.
Pack my box with five dozen liquor jugs.

[1] As a matter of fact Y had to change his method of writing the sentence in the last stage of his practice, in the way indicated, to keep from breaking down completely. He had been writing the sentence as a whole and at a uniform rate. He had to stop this maximum rate for the whole sentence and go slower in the hard places and spurt at the easy sections to attain the greatest speed and accuracy.

Pack my box with five dozrn liquor jugs.
Pack my box with fivedzen liquor jugs.
Pack my box with fove dozen loquor jugs.
Pack my box with five dozen l oqiuor jugs.
Pack my box with five dozen liquor jugs.
Pack my box wth five dozen liquor jugs.
Pack my ox with five dozen liquor jugs.

"The writing was not interfered with at all. I could give considerable attention to the tune without interference." The same test was tried by Z and X in the later stages of their practice. On February 2, X wrote: "There is no conscious spelling at all in fast writing so far as I can see. There is nothing but a sort of motor sanction for the movements as a whole. I never think of the letters or the copy. When a difficulty occurs I merely have to find my place in a series of movements instead of getting the particular letter or word. The idea of both letter and sentence seems to be dropping out completely. The movements for writing a sentence are made in distinct groups or bunches. One reason for this is to surely find the first letter of such a group. Some of these groups have a tendency to fuse. The tendency seems to be to unite the whole sentence into one group." Five days later he wrote: "I thought there was a slight motorization corresponding to the former spelling of the letters still going on, but while writing at the usual rate today I could whistle or hum a tune without any distraction save that caused by the extra attention put upon the tune. When a hitch occurred I had to stop my singing and focus my attention on the keyboard. In these cases I think some spelling was done. . . . . For several days I have found myself attending rather carefully to the sound made by the letters on the machine and thought this in some way helped call up the succeeding movements and assisted me in keeping my place in the sentence. Today I could sing or whistle and write as well as ever, though this shut out both the spelling and the sounds made by the writing."

Ten days later, Febraury 24, the mental adjustment for the word, i.e., visually locating the first letters, etc., could very well be made while the last letters of the previous word were being struck by the fingers. The spelling necessary for initiating these letter-making movements could also be attended to some little distance ahead of the fingers, so that the writing of the sentence was absolutely continuous. In the earlier stages, the records showed a break or pause at the beginning of certain words in the sentence, marking the time required for making the

mental adjustment necessary for writing these groups. Now the necessary attentive direction for running through the movements was given ahead. The whole sentence has become a group of closely connected movements, which attention controls and directs as a unit.[1]

(2) Fusion of the Spelling and Locating Processes and Development of Motor-tactual Control.—It was extremely hard to determine how the sequence of the movements was controlled in this stage. The learners repeatedly stated in their notes that they often found themselves unconscious of the word they were writing or of their place in the sentence. X thought that the group of movements representing the practice sentence was set off by looking at the first letter of the group on the keyboard, and that all the rest of the movements in the group were made in a wholly unconscious way. But fixating these letters was itself habitual and semi-unconscious, for the mental pauses, he said, might occur at any point in the sentence. It seems that the spelling and locating processes have fused and that the movements are now guided, both as to direction and succession, as in the advanced stages of touch writing, by attentively following at the beginning of this stage somewhat in detail, later, more and more generally, the motor tactual image of the group as a whole.[2] It is to this that attention goes. Improvement consists in handing over more and more of this direction to the subconscious centers and in pushing attention ahead to the control of the harder groups encountered in the writing.

We have seen from what precedes how the first actual whispered pronunciation of the letters gradually gave way to a more and more incipient pronunciation and this in turn to an actual and then to a more and more incipient group spelling, itself superceded by an unconscious "touch spelling" in the expert stage. A stage where the individual movements came to be initiated and guided by a motor tactual image, or sensations of previous movements in the series, instead of by a conscious spelling. But it hardly appears from what has been said how very

[1] The writing of our professional subjects showed the same thing. For long stretches in the best parts of their records their writing was absolutely continuous. (Compare H, Fig. V, p. 88).

[2] The word "following" is to be understood to mean for the early part of the stage actually guiding and controlling the movements, in the latter part of the stage as coming after and give a certain sanction to the processes which it formerly controlled. This relation is true of the habits of all orders in all parts of the work.

gradually these changes took place. It was determined that a sort of half conscious incipient mental spelling occurred and was required for months after it seemed that all traces of the spelling had disappeared.

When word and phrase associations had developed enough to noticeably affect the writing Y wrote in his notes: "I now notice no trace of the former spelling, not even when I attend to it. The writing of this practice sentence merely means a bundle of finger movements which take care of themselves, plus a few visual factors described below. But I have noticed for several days a marked tendency to get the order of these movements wrong. I often get the position of the letters interchanged, more often strike two letters simultaneously. When I try to avoid this I find myself returning to my former incipient or actual spelling which promptly corrects it." During one of his special observation tests X wrote: "Just for an instant today, when my attention was half directed to it I found myself still incipiently pronouncing every letter as I wrote, for several sentences. I had for a long time felt that no more spelling was done."

In typewriting there seems to be a rather definite boundary to the organization of habits. In fact the possibility of forming higher-order habits seems to vary directly with the complexity of the work. The development of phrase associations in the end reaches a practical limit, due to the number and variety that are used, relatively few recurring often enough to become absolutely automatic, so that no further organization is possible in that direction. If at the same time no further gain can be made on the physiological side (in greater ease and precision of fingering, etc.) and if all possible perfection has been reached in the elemental associations, increase of skill is at an end—unless indeed some further improvement can be made in the more general psychical factors next to be considerd. As a matter of fact, however, since these more general habits are acquired in the actual writing and developed and perfected along with the others, little progress is to be expected after the attainment of a considerable outfit of well automatized phrases.

C. SOME MORE PURELY MENTAL HABITS ACQUIRED IN THE COURSE OF THE PRACTICE. (LEARNING TO LEARN).

1. Learning to Short Circuit.

Besides the development of the specific "Habits of Manipulation" described above, their continued organization into habits of an ever higher order and the further perfection of these, there were developed in the course of the practice certain general Habits of Control or, if one may use the phrase, more purely psychic habits than the special typewriting habits above described. The first and foremost of these was the development of a regular method of "short circuiting" which proved generally helpful in the development of all the special typewriting habits described above.

All the special "habits of manipulation" go through the same general course of development. In the beginning everything must be done in detail, and each detail represents, at first, a difficult task requiring the help of many temporary associations. A long step forward is taken when these temporary associations and all processes, psychic and physical, used to build up the more direct associations are discarded under the strain of the desire for speed. To use the development of the letter association as an illustration, a beginner must pronounce each letter to be struck, mentally locate it on the keyboard, go through with a series of movements and mental processes necessary for getting his fingers to the keys then consciously initiate the final letter-making movement—and this for each letter he makes. As the letter association is developed this step-by-step method of locating and striking the individual keys is abbreviated, changed, supplemented, modified and finally superceded by a single direct letter-making movement as we have seen. A similar change takes place in the development of the word and phrase associations. Each is built up by means of many temporary associations and helps which must be gotten rid of as more direct and economic associations are formed. In the course of the practice the subject learns just how long to use these temporary helps and when to get rid of them; and learns how and when to lay hold of new adaptations; in a word, he learns how to "short circuit."

2. *Learning How to Meet Difficulties.*

Along with the learning of how to "short circuit" there was developed an advantageous method of dealing with the many special difficulties encountered in the learning. At any stage of practice the learners found some letters, because of their position on the keyboard or the infrequency of their occurrence, distinctly harder to make than others. The same letter may be easy in one combination, and hard in another; certain words are long and difficult to spell and the reaction to their letters troublesome; at certain stages many conflicting associations are formed. In the course of practice the subjects learned how to meet successfully all the difficulties that were encountered; in particular they acquired the habit of not shirking them, but, on the contrary, of attending carefully to each until it disappeared. A few concrete illustrations will make clear what is meant.

One of the most serious general difficulties which the learner encounters is due to the fluctuations in his own efficiency, elsewhere fully described (pp. 120, 130-131). Our records and introspective data show that in every stage of progress there are such variations in efficiency and that they affect every part of the work. There were good days, and good periods within a single test when every part of the work went easily and well, other days and periods when every part of the work had to be forced. It was found for example that a touch writer when writing copy of approximately the same degree of difficulty made during certain minutes of a test from two to two and a half times as many strokes on the machine as in other minutes of the same test and this when trying to write at a maximum rate throughout. Variations in daily efficiency were almost as great. With practice the subjects learned to reckon with the fact that their ability to deal with the problems involved varied from moment to moment and from day to day, and gradually developed a way of meeting this variation in efficiency more and more successfully.

Another difficulty of an objective sort, but leading to a like absence of uniformity was found in the difference in the copy, especially when the S. M. was used. Long words were found harder to retain than short ones, unusual words than familiar ones; a short sentence was more easily memorized than a long one, one that could be easily broken up into units of thought of the proper length than one whose form or meaning

was obscure. In order to get the best results the learner had to take into consideration all the difficulties which the nature of the copy presented. He learned to gauge more accurately his ability to hold that particular copy on that particular day. On off days and during his bad periods he involuntarily lessened the amount taken, read it more slowly and carefully, motorized it more strongly, etc. The moment it began to get so vague as to interfere with the best work on the keyboard it was refreshed. In the early stages of practice this was not done. The effect of practice in this regard was shown in a striking way by the mean variation for the average amount of time spent upon each word of the copy and for the total time spent in learning the copy. As practice continued both decreased showing that in the later stages of practice there was much more regularity from day to day in the matter of getting and holding the copy.

Another difficulty that had to be mastered by the learners was due to interference of associations to which reference has already been made (compare pp. 44-45, 81-83, below). This difficulty gave special trouble at certain rather definite stages of advancement. As Z expresses it: "When syllable and word associations have been almost perfected a sharper attentive direction is required to prevent interference of associations." In the course of practice, however, the subjects learned to so manipulate and control their attention and effort that fewer mistakes due to this cause occurred. Perhaps the most serious difficulty unconsciously eliminated in the course of practice was that occasioned by the "shifting of attention" in the S. M., already described. This was completely mastered (see pp. 52-54). In short the expert typist has learned that it pays to meet squarely every difficulty as it occurs and to conquer it at once. We might almost say that her *nervous system* knows that she must go slow enough to avoid every mistake. She never gets "rattled" and seldom loses her typewriting psychosis. The amateur has not yet learned the practical significance of avoiding mistakes, so crowds himself into his undoing on the "bad days" and at the "critical stages" in the learning.

Teachers of typewriting have attempted to guard against the evil effects caused by an improper adjustment to all these difficulties by giving special practice on the harder combinations of letters and having their learners practice most of the time with special reference to accuracy and only a part of the

time with attention directed to speed. This has the effect of reducing the number of special difficulties encountered at any one time and makes the writing more even.[1] A fact worthy of special emphasis is that *our learners, who were left without the guidance of a teacher, worked out unconsciously a method of dealing with the special difficulties encountered in typewriting, which had the same result in the end.*

The degree and nature of the gain made in the formation of this general habit varied, with the stage of practice and the different subjects. Some learners paid dearly for their lesson. At the "critical stages" the difficulties generally got the better of the learners and caused retardation and arrest of development. But it was at such times as these that the evil effects of mistakes became apparent and forced the formation of this most necessary habit.

3. Acquiring and Maintaining a Favorable Attitude of Feeling.

Another general habit formed in the course of the practice was the development of a generally favorable attitude or helpful feeling tone, which, in the expert stage of writing, approached the condition of steady interest. The following changes in the learners' attitude were observed as practice progressed. In the beginning all the learners were greatly interested in the work. They enjoyed the practice thoroughly and were always anxious to take up the work anew each day. The accompanying pleasant feeling tone seemed to have a reciprocally helpful effect on the writing, and the learner's attention seemed of itself to remain concentrated on the work.

Continued practice, however, brought a change. In place of the spontaneous interest of the beginning, attention, as we have already seen (p. 43) tended strongly at certain stages of

[1] Mr. Harold Bauer, the celebrated pianist, in speaking of the grind of practice which many pupils think essential to the development of piano technic, said in an interview:

"I have found in my own experience that it is absolutely unnecessary. I was a violinist first, as you know, and the career of a pianist was, in a way, forced upon me after I was grown up. But I have never regretted the time spent with the violin—it taught me how to practice.

"When I realized that I was to become a pianist, I held a consultation with myself. I had practically no piano technic, and I realized that I had not time to go through years of merely mechanical work, so the question was, How to achieve the best results in a limited time? And in working out the solution of the problem I found that properly directed mental work away from the instrument reduced the amount of necessary mechanical practicing to a minimum.

"I made out my programs and picked out of every composition the passages that offered me the greatest difficulties. Upon analyzing

advancement to wander. A general feeling of monotony which at times approached the feeling of utter disgust, completely changed the learner's attitude. The writing became a disagreeable task while the unpleasant feelings hindered the writing and learning, perhaps directly and certainly by drawing attention from the work to themselves. Such expressions as the following were prominent in the notes at this stage: "I have not noticed for a long time any favorable attitude resulting when I can write easily and fast. I formerly felt good as a result of knowing this. But the 'fun' of writing is wearing off and has reached the indifference point long ago. The writing today approached the nature of a 'bore'." A few days later the same subject wrote: "The practice is now a decided 'bore', the writing a provoking task."

As still greater skill was acquired this unfavorable attitude disappeared. All the learners again took an interest in the work; their general feeling tone once more became favorable and the writing movements distinctly pleasurable. Their acquired habitual attention approached or even exceeded in perfection the eager spontaneous attention with which they began. In his notes for the last stages of his "practice sentence" writing, X said: "I would now rather write than to eat. I keenly enjoy the 'feel' of the movements because I can make them correctly and fast." This was also the attitude of Miss Carrington, the expert. She took an artistic pride in the fact that she struck her letters with so near the same intensity that they were as perfect as the best of print. She could copy anything or write a practice sentence until fatigued and thoroughly enjoy it. To her the writing seemed like play and was as much enjoyed, though she worked harder and paid closer attention to the work than did any of the blundering learners who disliked it. Developing this permanent interest in the work was one of the accompaniments of the learning.

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these, I found that in every such passage there was one special sticking-point, and that when once the right position of the hand for it was decided upon, all the rest of the passage was simplified.

"This theory I have applied in my teaching with excellent results. Analyze the passage that seems to bristle with difficulties, pick out the most difficult spot—there is always one particularly refractory measure on which everything else hinges; master it, and the position of the hand then practically determines the position of the hand for the whole passage. I encourage my pupils to do as much work as possible away from the instrument, though of course that depends largely upon the student's capacity for mental concentration." (Musician, Sept., 1908, p. 403).

4. Learning to Keep Attention Focused on the Wiritng.

Almost inseparably associated with the development of the generally favorable attitude of feeling just described, there went the development of a habit of wrapped attention. In the early stage of practice there were frequent lapses of attention, periods long and short, when attention naturally turned to outside interests instead of being held close to the work and pushed to higher forms of direction as soon as possible. Other periods when the mind was a blank, the reaction slow, and the writing done on a lower plane than the learner was capable of at the time. When an expert skill was attained a habit had been formed of keeping attention so constantly applied to the task in hand that nothing could distract. What the relation between the "favorable attitude of feeling" and the wrapped spontaneous attention is it is impossible to say. It seemed to be the favorable mood that made it possible for the learner to keep his attention so constantly focused on the writing that irrelevant stimuli could have no effect. In fact the development of the favorable attitude of feeling might be stated in terms of attention and interest, for with it always went the ability to keep attention closely riveted on the work. Close attention to the work, success, improvement, and a pleasurable feeling tone always went together (see pp. 149-152).

The vital necessity for such a habit of attention can easily be made clear. The natural tendency to lag (a principle of mental economy) continually favored the lower-order habits, those most easy and automatic. Long after a way of locating or making certain letters and words had been superseded by a higher and better way the old habits tended to recur at every relaxation of attention. This tendency could be overcome only by keeping attention so persistently and strenuously applied to the writing that the highest possible habits were used. It was the development of this habit that forced the learners to make new adaptations and short cuts in method and enabled them to leave the old and less economic ways behind as fast as they were sufficiently perfected to permit the development of new and better ways of writing.[1]

[1] In discussing Bergstrom's theory of interference of association (**Psy. Rev., Mon. Supp.,** Vol. V, p. 47) Bair says: "If there is actual interference as defined above, it is due to indisposition rather than inability. We become a slave to a habit because we will not make an effort to free ourselves from it by a better or more desirable one." (Compare this study, pp. 91-95).

The development of this habit of wrapped attention or interest, and the acquisition of a generally favorable feeling tone is as important for learning as the development of any of the special "habits of manipulation" described above.

5. Learning How to Attend and Economize Effort.

Another general habit, one closely allied to the two which immediately precede, and one of major importance, I shall, for want of a better name, call "learning to attend." In the early stages of practice the learner's efforts were not always well adapted to the work. Many purposeless motor discharges accompanied the writing, such as rigidity of the body, jerky and meaningless movements of the fingers and hands, all sorts of overflow movements, affecting various parts of the learner's body. The learner's energy could neither be released in the right amount nor advantageously directed. The following phrases are taken from the experimenter's observations of Z in his earlier tests: "Hammers the keys, spells so loudly that he can be heard in all parts of the room, constantly wriggles about on his chair, lifts up the table with his knees, grits his teeth, trembles and literally uses his whole body to write." Z's introspective notes for the period showed that the waste on the mental side was equally great. His energy could not be advantageously directed nor his voluntary attention rightly applied. The same was true of the other learners.[1] With increase of skill the learners gained better control of the disposition of their energy. They somehow acquired the knack of releasing only so much energy as could be effectively applied, and of directing it in the most economical manner. Almost no energy was wasted; all their activities came to be controlled more and more directly by the one purpose of getting with all possible speed through each series of movements to be made; their voluntary attention when applied to the writing approached in general effectiveness the perfect spontaneous attention which it supplements.[2]

In addition then to the development of the special "habits of manipulation" described in the previous sections, there is this improvement in general method—"learning to short circuit," "learning how to meet more successfully the special diffi-

[1] Compare "A Preliminary Study of Some of the Motor Phenomena of Mental Effort," Lindley. **Am. Jour. Psy.** Vol. VII, pp. 491-517.

[2] Compare "Periodicity and Progressive Changes in Continuous Mental Work" by Seashore and Kent, **Psy. Rev., Mon. Suppl.,** Vol. VI, March, 1905, pp. 63-91.

culties'' encountered in the learning. ''developing a generally favorable attitude'' toward the work, ''learning how to attend,'' etc. Not a little of the progress made by our learners was due to the development of these special ''habits of control.'' A fact, of far reaching practical importance, pertaining to the formation of these more general mental habits is, that most, if not all of them, when developed in the S. M. learning were carried over to the T. M. learning and used with good effect, a fact which has obvious bearings upon the much disputed question of ''formal discipline.''

IV.

THE RETENTION OF TYPEWRITING SKILL.

Our next step logically should be the explanation of the learning curves; but before we proceed to that it will be well for us to consider another group of experiments which is both interesting in itself and throws important light upon certain aspects of the learning process—a group having to do with the retention of the skill acquired.

A. THE MEMORY TESTS.

The last test of the regular experiments was taken by the writer in his T. M. practice on Jan. 16, 1906. On account of other duties the typewriter was not touched again by him until the following June. On June 1, 1906, and the nine days following, a series of 10 tests was made on the same kind of a typewriter used by him in his regular T. M. practice (a No. 5 Underwood) and under the same conditions as the regular tests. The typewriter was then not touched again for a full year, until June 1, 1907. Ten daily tests were then taken, with the same precautions as before. The following table shows the results:

TABLE II.

TESTS.	1	2	3	4	5	6	7	8	9	10	Ave.	Ave. Correct Strokes.	Per Cent Errors.
Last Reg. Prac., Jan. 7-16, 1906.....	1503	1509	1404	1572	1494	1436	1501	1455	1508	1698	1508	1475	2.21
1st Memory Test, June 1-10, 1906.....	1365	1421	1421	1433	1529	1443	1523	1504	1313	1472	1443	1391	3.54
2nd Memory Test, June 1-10, 1907.....	1390	1344	1345	1537	1681	1694	1634	1845	1761	1850	1611	1560	3.15
Average gain for last memory series.....											103	85	

As the table shows there was no loss of skill after a cessation of practice for a year and a half, but, what is still more surprising, an actual average gain of 103 strokes per day over the records made during the last ten regular tests; or, if we subtract the errors made an average net gain of 85 strokes per day. Before attempting to account for this unexpected[1] gain it would be well to describe the kind of relearning which actually took place during the memory tests.

B. RELEARNING IN THE MEMORY TESTS.

When the subject began to write, June 1, 1906, the visual image of the keyboard had almost entirely faded out.[2] Only two letters, the *a* and *p* could be located from visual memory. There was present a vague general image of the entire keyboard but the relative positions of the letters was forgotten. On June 1, 1907, there wasn't so much as an image of the rows of keys. The subject could not tell whether the letters on the keys were small or capital. By thinking hard of the keyboard for a time and moving attention about over it, visual images of *a, i, o, p, m, n* and *z* finally came up in their proper positions on the keyboard so that when the writing began the fingers had a definite place to move to.

In trying to draw the keyboard before beginning to write the location of such of the letters as could be located had to be variously figured out by the help of all sorts of artificial associations. The *t, h, g* and *y* were mentally located by the thought or sight of these letters in the copy calling up at once the muscular image of the movements required for striking their corresponding keys. As soon as these letters were thought of an actual feeling of strain was noticed in the fingers which seemed to guide attention to the proper position on the keyboard. While thus attempting to recall the position of the keys, if a visual

[1] Quite unexpected by the writer, though some similar results have been obtained by Bourdon, Swift, and others. See especially **L'Annee Psychologique,** Vol. VIII, 1901, pp. 327-340, and **Am. Jour. Psy.,** Vol. XVI, 1905, pp. 131-133.

[2] This description of the relearning is taken from the subject's introspective analysis of how the writing was done during the memory tests. While writing the first fifteen lines, necessary to revive the old associations, the subject stopped at any point long enough to record whatever observations were made. It is from these detailed notes of the writing of the first fifteen lines in each memory series and from notes written down at the close of each memory test that this account of the relearning is taken. The subject also attempted to draw the keyboard and to recall the position of the letters before the machine was touched in each set of memory tests.

image came in at all it followed the movement of attention and was called forth in each case by a motor image, instead of appearing spontaneously and originally in visual terms. This was true for all letters that could be visualized. The following quotation is taken from the notes written June 1, 1907, before any writing was done: "After half an hour's work in trying to visualize the keyboard I find it impossible to definitely locate all the keys. My visual image is too vague in every case to locate the letters. The thought of the letter will not call up a visual image or tell me just where that letter is. I am exceedingly anxious to get at the writing to see just what I must do to get my fingers to the different keys."

The keyboard, as in the original experiment, was covered in such a manner that the writer could see no part of it. He did not even glance at the keyboard before starting to write. As soon, however, as the hands were in proper position for writing, the thought or sight of the letters called up directly the movement of attention to the exact position of the keys. A few keys could not be located even so and had to be referred to visually before the fingers could find them. Moreover, the position of the letters was remembered by combinations or groups. The letters within a word were more easily located than isolated letters or those at the beginning of words. If the first letter of a word was known the fingers of themselves went to the other keys. Many cases were observed where the subject could not find the key at all when the letter began a word, but when it came within a familiar word the same letter was struck without difficulty and without conscious direction. The following quotation written by X before his second memory tests were begun is typical: "Before beginning to write," he says, "I tried hard to locate the 'd' key but without success. Just now came to the word 'day' and was startled to find the right finger on the 'd' key before I was conscious of what I had done. I had actually written 'da' before my past trouble in trying to locate the 'd' took possession of consciousness, when I stopped to write this note." "U" was another letter whose exact position was not remembered. "No matter how hard I tried," wrote X, "my attention and hands would not go right when I tried to locate it. Just now I had to write the word 'result'. Attention of itself did the right thing and my fingers had already made the 'u' when the afterthought flashed up that I did not know where it

was. It made me feel queer to realize that it should ever have been hard; it came so easy after writing 'res'."

This is an important point since it shows that *the skill can not be recalled by a sheer act of will but requires the exercise of the muscles themselves to re-establish the chain of subconscious reflexes.* It is also important for the "warming up" (see p. 103). There must be an actual physiological limbering up before attention and the muscles will work smoothly and quickly again (compare pp. 106-107).

By the time the first thirty words of page 145 of Munsterberg's "Psychology and Life" had been copied, the position of all the letters had been so well relearned that any key could be struck directly as needed. All letter associations and most word associations had been fully revived.

In writing the first few words attention had to move, as in the early stages of learning, to the exact position of the letters to be struck before the fingers could start, and the movements required for striking the keys had to be carefully attended to throughout their whole course, except for the last letters of the easier words. Very soon, however, this pre-location fused with the motor-tactual feel of the movements. The sight of a letter called forth at once a movement of attention in the proper direction and to the proper distance which came simultaneously with or just before the required movement. The separate movements could soon be so quickly and easily made that consciousness needed only to concern itself with the guidance of the group as a whole as in the word and phrase association stage. All took place almost too rapidly to be observed, the whole process being completed while writing fifteen lines. The relearning was recapitulatory only in a limited sense. The general course was the same but all of the steps were rapidly abbreviated and some omitted entire.

As might be expected it was the latest acquired associations that were hardest to revive. Certain general habits seemed also to have been dulled. There was trouble, at first, with the attentive following of the course of the movements. Attention could not be held as constantly or steadily on the writing as formerly. It would not follow so readily or easily the course suggested by the letters and words of the copy and its scope was more limited it seemed. A sort of orientation to the task of writing seemed to be lost. The general feeling of "at-home-ness" on the keyboard

was noticeably weakened. The little fingers had to stick much closer to their respective positions for a time. The general motor-tactual discrimination was greatly dulled and none of the mental processes worked so quickly or easily right at first. The subject was more easily fatigued, as evidenced by severe pains in his fingers and wrists. At the close of his test on June 2, 1907, X wrote: "One of the things that seems to prevent rapid writing is that the hands and fingers get so tired. They begin to feel numb and ache soon after the writing starts. If it were not for this the score would be much higher than it is. All difficulties seem to have disappeared and the associations or mental processes involved in the writing, which worked rather sluggishly at first, now work more spontaneously and unhindered, it seems, than ever before."

C. EXPLANATION OF RESULTS.

The facts here to be explained are the rapidity of the relearning and the actual gain in skill shown by our second memory tests (see Table II and Fig. IV). It can hardly be said that the ten 10-minute practices are responsible for the gain. For if this were the case, we should still have to account for the fact that a *10-minute* practice period showed greater gains after an interval of no practice for a year and a half than a *60-minute* period at the end of the regular experiment, when there were no signs of a plateau in the learning curve.[1]

The percentage of errors made in both memory tests was somewhat greater than for the last 10 tests of the regular writing (see Table II above), suggesting that the learner tried harder and put more attention on speed in the memory tests. This would tend to make the score somewhat higher for the memory tests, but this lack of conscientiousness on the part of the learner will not account for the marked increase in score for the second memory tests where we have as compared with the results of the first memory series a higher score and a decrease in the percentage of errors. There seems to have been an actual increase in skill during the rest interval of a year and a half.

How is this to be explained? When taken with the observations of the learner which credit the improvement to the ease and accuracy with which the old associations worked, rather than

[1] It will be recalled that in the regular learning fifty minutes extra practice was taken each day in addition to the regular ten minute tests.

to any new adaptations or short cuts in method, this fact might be thought to mean that the associations previously formed had been slowly perfecting themselves subconsciously by some sort of neural growth process which completed itself during the interval of no practice, as Burnham and Cleveland believe.[1]

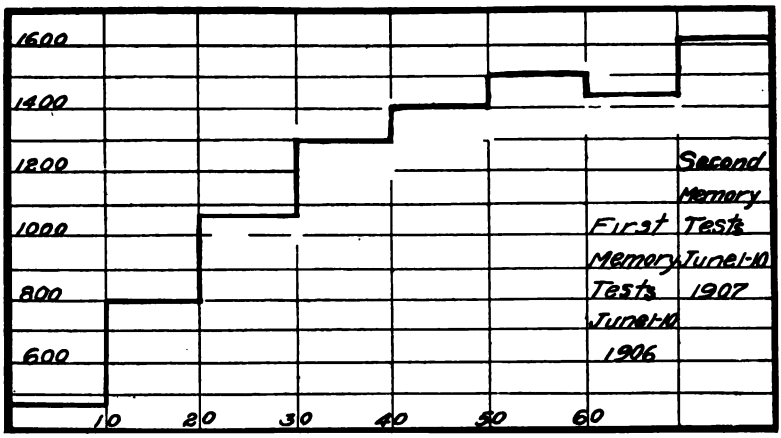

FIG. IV

Figure IV, is a diagramatic curve for X's T. M. learning which enables us to compare at a glance the results of the memory tests with the results of the regular practice. The successive days of practice are shown along the horizontal axis, the progress made, measured in strokes, along the vertical axis. The horizontal bars in the curve when measured by the vertical axis show the average strokes made for the period of practice indicated by their length.

Such a view is attractive and may in a measure be true but our experiments give no definite evidence for it. The increase in score shown by our second memory series was due, so far as we could make out, rather *to the disappearance, with the lapse of time, of numerous psycho-physical difficulties, interfering associations, bad habits of attention, incidentally acquired in the course of the learning, interfering habits and tendencies, which, as they faded, left the more firmly established typewriting associations free to act.*

[1] **Am. Jour. Psy.**, Vol. XIV, 1903, pp. 382-396; Vol. XVIII, 1907, p. 297. Compare also articles by Bryan and Harter and Swift, **Psy. Rev.**, Vol. VI, July, 1899, p. 358; Garman Memorial Volume of Studies in Philosophy and Psychology, Boston, 1906, pp. 306-307. Here the rapid rise of the learning curve after a plateau, and the sudden improvement made in learning a foreign language, are attributed to neural growth.

The following facts are given in support of this view: (1) Such hindering associations were developed in all stages of practice, and at the "critical stages" in great masses, forming a serious impediment to progress. (2) After the rest of a year and a half these conflicting associations and hindering tendencies had noticeably disappeared.

The evidence furnished by our introspective and objective data in support of the first of these points is elsewhere (pp. 118, 143-144) described. Confirmatory evidence on the second point, beyond the introspections of the subjects, is, we believe, to be found in a comparison of the records of the two memory series. During the first memory series, after a rest of only four months, the absence of difficulties and the greater ease were not observed by the learner. There were more mistakes and a lower score than for the last 10 regular tests. The typewriting associations had been somewhat dulled and the interferences had not yet all dropped out. A year later, during the second memory tests, the absence of difficulties and the greater ease had become so prominent as to attract the attention of the learner (see p. 79). His notes state that he was influenced by the good showing made in his first memory series and therefore tried especially hard to write fast in the second memory tests, attending more to speed than to accuracy. But the errors have now slightly decreased and the score is better than ever before. If the restraining influence of hindering associations had not disappeared the subject would certainly have made not *less* but *more* mistakes and crowded himself into a "breakdown." *We, therefore, conclude that it was the disappearance of the interfering associations and tendencies naturally developed in the course of the learning which made the old associations work so easily and caused the increase in the score.*

We would not slur over the fact that our introspective data come from the relearning of a single subject, but the general fact of improvement after long intervals of no practice has been demonstrated several times by others (cf. footnote page 76 above), and a tangible explanation like that of interferences seems to us better than a more intangible one based upon neural growth. It is not at all unlikely that some sort of latent development or neuro-physical growth does take place during intervals of no practice through the nutrient changes set up by the action of the blood to the exercised parts. Our data gives no

grounds for denying such a hypothesis, but we should expect such an influence to be operative during short, rather than long, rest periods—periods within which the direct effects of exercise might still hold over in some strength.[1] It is also probable that the particular brain processes involved in a given activity become dulled or fatigued with long continued exercise giving rise to the feeling of monotony or aversion for that particular task, so common in all forms of learning yet studied. But such fatigue would tend to aggravate the interferences already formed and would lead to the development of others while the neural growth, if such there be, would hardly balance the loss occasioned by the fading of the associations. It is also true that something is due to refreshment of interest. Long practice leads to fatigue and *ennui*, and in matters of strength and skill to "staleness", all of which can be relieved by rest or change of work. But a difference in freshness of interest would hardly account for the difference between our first and second memory series. And it must not be forgotten that fatigue and loss of interest lead to lapses of attention and these to a repetition of blunders which are psychologically incipient false associations and bad habits. The advantage of rest and change of work would therefore probably be double, removing at one and the same time both the *ennui*

[1] That such is probably the case is suggested by the following facts: After a hard day's work on this paper it was observed that before going to sleep at night hypnagogic imagery, pertaining to the work, invariably appeared and took possession of consciousness. The former mental activity tended to persist in a sort of sub-conscious way and was invariably present in the writer's dream consciousness. When he had been dealing with a point that could not be easily solved his dream and hypnagogic imagery took the form of some indeterminable struggle involving various forms of imagery. At such times the work served as a veritable Banquo's ghost which presented itself at every lapse in waking consciousness and dominated completely his dream imagery, suggesting that the severe, systematic nervous activity of our waking life is continued for a time in a sort of sub-conscious way after the stimulus ceases to be applied. It seems as if the nervous system acquired a sort of momentum which keeps the stimulated parts acting for a time.

This persistence of one's immediately previous occupation or "Preservation tendency" is still more strongly suggested by the facts observed during the vacation which immediately followed the completion of this study. During the four weeks which immediately preceded this vacation the writer spent twelve or fourteen hours each day working on the study. During the week's vacation which followed this period of strenuous work the writer's mind was literally flooded, at each lapse in consciousness, with the problems and difficulties encountered in the writing. For the first three nights of this vacation he worked continuously on the study in his dreams. The new life and strong stimuli furnished by his recreation were insufficient to counteract or supplant the effect of the previous stimulation. The "brain machinery" set going by the month's strenuous work, though in part

and the incipient bad habits of attention to which it was leading.[1]

The importance of all this for acquisition in general is evident. In most learning and in the acquisition of any complex form of skill the formation of many conflicting associations would seem to be a natural, but *unnecessary* accompaniment of the development of the associations and habits involved in its mastery, as it was in the typewriting. Without expert direction from a skilled, sympathetic teacher and sometimes in spite of it, the learner forms many interfering habits and trains himself in many mistakes *many of which never make any definite objective manifestation of themselves.* These must be carefully eliminated or overcome before higher skill is possible. In learning to typewrite there is no more important problem than keeping these interferences down to a minimum. With the best possible direction and the most guarded practice many hindering tendencies, both of thought and action, will be formed. The best results for learning will be obtained when the periods of practice or study are, on the one hand, of such length as will give the greatest amount of practice to the habits to be formed, with the least opportunity for making mistakes or developing interferences, and when the periods between practices or study are, on the other hand, of such length as will insure the most complete dropping out of the interfering tendencies naturally formed in the course of practice, with the least amount of fading of the associations and habits to be established. In other words, when the most economic periods of work and rest have been found for the individual in the mastery of the subject or task in question.

The whole question of the most economic periods of work and rest for all kinds of learning is here raised. Besides being important for giving an opportunity for the dropping out of

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suppressed by the new experience, kept, nevertheless, grinding away for a time in this sub-conscious way. It was more than a week before the new experiences overcame the momentum induced by the long period of systematic work. The bearing of this on the problem of the most economic periods of work and rest is obvious. One must work long and hard enough to get this semi-unconscious assistance, but not long enough to spoil it by fatigue—make it erratic or introduce exhaustion phenomena in it and other parts of the psycho-physical apparatus.

[1] At this point an important question is suggested. May not the monotony and ennui or fatigue for the task as a whole, observed in this and all the learning studies made, be caused by the many psycho-physical interferences naturally developed in the course of the learning? Any wrong tendencies of thought and action would naturally retard the learner's success, while the ennui and unpleasant feelings which attend the failure would serve to bring about a cessation or change of work, because it is biologically better to stop and rest, when no improvement can be made, than to go on cultivating mistakes.

the interfering associations and tendencies naturally built up in the course of the learning, the time interval between practices or study periods *may be found to be important in and of itself.* It *may be* that the *ennui* or seeming fatigue for a given kind of work is due not so much to the interfering associations as to neural fatigue, that a maximum degree of efficient effort cannot be kept up by the learner with any sort of assistance, that mental facts and associations may be acquired under certain conditions of learning faster than they can be assimilated neurally,[1] that certain regulated periods of rest are needed to give the best results for fixing the associations to be formed. There is no more important or necessary step in learning than to fix definitely *all* the elemental habits later to be used in the formation of the higher-order habits finally to be attained. For this both time and a certain amount of practice is needed. Whether it would be best to practice continuously, provided the practice or study could be carried on without mistakes, or whether it would be better to allow for vacations in addition to the rest periods required for recuperation of nervous structures exhausted in the work, we do not know. One purpose which vacations and the longer periods of rest unquestionably serve is to give opportunity for the dropping out of the interfering asosciations which naturally develop and accumulate in the course of the learning. Whether or not the learner at certain stages of advancement is unable to deal successfully with this difficulty in any other way than by taking a rest it is impossible to say with any degree of assurance. The fact that such difficulties are very often successfully met in *some* cases, would argue that they might be in many or all (compare this study, pp. 160, 166). At any rate it would be worth much to know the proportion of practice and rest that would give the best results in the different fields of learning and to know more definitely all that this period of rest means, but much painstaking investigation will yet be needed before we shall arrive at this knowledge.

[1] Cleveland's observation (**Am. Jour. Psy.**, Vol. XVIII, 1907, p. 298) that chess players could not play in proportion to their knowledge would seem to be a case in point. Though it by no means follows that a vacation is all they need. A different sort of playing or a more careful use of attention might solve the problem as well or better. In that case the mass of material from which the new direct associations are formed would not hinder but help in building the new associations since progress in learning seems to mean the elimination of most of this material and the reorganization of the rest into associations that are more economic and direct. In learning to typewrite it was found better to practice always with the highest-order habits possible.

V.

HOW TYPEWRITING HABITS ARE ACQUIRED.

We may now return to the main problem we set ourselves to solve and consider the facts which will assist us in explaining our learning curves. The analysis of the learning consciousness which precedes has shown what our curves stand for psychologically. Numerous special habits arose, and it was the inception, development and perfection of these special habits of all kinds and grades that caused the total upward movement of our curves. In explaining the form of our learning curves we shall first consider their general characteristics, their rapid ascent at first, and later slow and more gradual rise, then attempt to explain their fluctuations and individual peculiarities. But even their most general features can not be understood until it has been more definitely pointed out how these special typewriting habits are acquired.

A. ORDER OF ACQUIRING THE HABITS WHICH CONSTITUTE TYPEWRITING SKILL.

Bryan and Harter *(Psy. Rev.,* Vol. VI, p. 357), the pioneer workers in this field, state that all the habits involved in learning to receive the telegraphic language "make gains simultaneously but not equally." This they inferred from the general character of certain curves obtained by having their subjects receive telegraphic messages, first in the form of disconnected letters, next as words not making sense, then connected discourse or words in the form of sentences. For the early part of this practice the letter, word and connected discourse curves rose rapidly together. After several weeks of practice the connected discourse curve showed a very rapid rise while the word and letter curves continued to rise but slowly. The fact that the word and letter curves continued to rise slowly after the connected discourse curve had begun to rise so rapidly proved, Bryan and Harter believed, that all forms of habits, high and low, were making gains together. That all curves rose at an almost equal rate in the early part of the practice meant, they believed, that the chief gain in this stage was due to the development of letter and word habits. The later rapid rise of the discourse curve over the word and letter curves meant that in

this stage the gain was mainly due to the development of the higher language habits involved. Upon these conceptions they based their explanation of "plateaus". "A plateau in the learning curve means", they say, "that the lower order habits (letter and word habits) are approaching their maximum development but are not yet sufficiently automatic to leave attention free to attack the higher-order habits." And they add, "the length of a plateau is a measure of the difficulty of making the lower order habits sufficiently automatic" for use as elements in the higher-order habits. The critical question here is the explanation of "plateaus". Is there such a time sequence in the development of the habits of different orders as this explanation implies?

Swift from observations on this point made in his several learning studies concludes that there is not. In one of his notes he states: "Two specific associations were growing together, one developing the other forming." Again, "There is clearly no separation of periods in which lower and higher order habits are formed. All factors of the perfected process have clearly been present almost from the start" *(Psy. Bull.,* Vol I, p. 299). In a later study, "On Beginning a Language," this earlier observation was confirmed. "Higher order habits," he says, "made their appearance early in the work, fugitive at first and not easily detected, but they soon became so strong and permanent as to be easily observed. All the habits acquired were in process of formation almost from the beginning" (Garman Memorial Volume of Studies in Philosophy and Psychology, Boston, 1906, pp. 304-305).

Leuba in an investigation of "Learning to Make Hand Movements" *(Psy. Rev.,* Vol. XII, p. 355) confirms Swift's observations on this point. He writes: "Even though the several psycho-physiological processes involved in learning to write German script, under the conditions of this experiment, should appear in a definite order of succession, they do not reach complete maturity before the next one becomes possible. On the contrary, several of them grow together, and, before they have been fully perfected, the next ones are already in operation."

These observations confirm one of the most important inferences made by Bryan and Harter, namely, that the special associations involved in receiving the telegraphic language made

gains simultaneously *(Psy. Rev.,* Vol. VI, p. 356), and give further evidence of the manner in which special associations develop and grow in the process of learning, but they still leave open certain important questions upon which our data sheds light. We have been able not only to confirm the general observations of our predecessors, but also, as it seems to us, to show why certain stages in learning such things as typewriting were of a "critical" nature and tended of themselves to bring about arrest of progress with corresponding "plateaus" in the learning curve.

Let us return to our drum records which give an objective picture of the writing in every stage of advancement, and furnish, therefore, an index of how the special associations were developed. Figure V shows sections from representative records. "A" is a portion of the first record of one of the special subjects who was learning to write by sight. He did not know the location of any of the keys, so that each of the steps required to make a letter in this early stage was more or less of a problem for him. "B" is a portion of the third record of Z's regular S. M. test. Unlike the other subjects, Z very early tended to locate his letters in groups and so began earlier than the other learners to acquire syllable and word associations, shown by the quick succession of the letter marks on his records. "C" is taken from a typical record of X's S. M. writing when he had reached an average rate of about 90 strokes per minute. This record shows letter associations in all stages of development, some word associations developing, and one phrase association operative. The "D" records (from the records of Z) represent a somewhat later stage and are similar to "C" except that more word and phrase associations are used. Habits of all grades are now plainly operative and in various stages of perfection. Half the writing is by word and phrase, as witnessed by the rapidity and continuity of the strokes. "E", a section from the practice sentence writing of Z, illustrates a semi-expert stage, as does also section "F" from the record of Miss A, who could copy at an average rate of fifty words per minute. Phrase associations are characteristic of the stage reached, and word and phrase associations need only to be further perfected to establish the supreme skill pictured in "H", a section of one of the regular writing tests of Miss Carrington, the finished expert. All word and phrase associations are now so far perfected that the writing

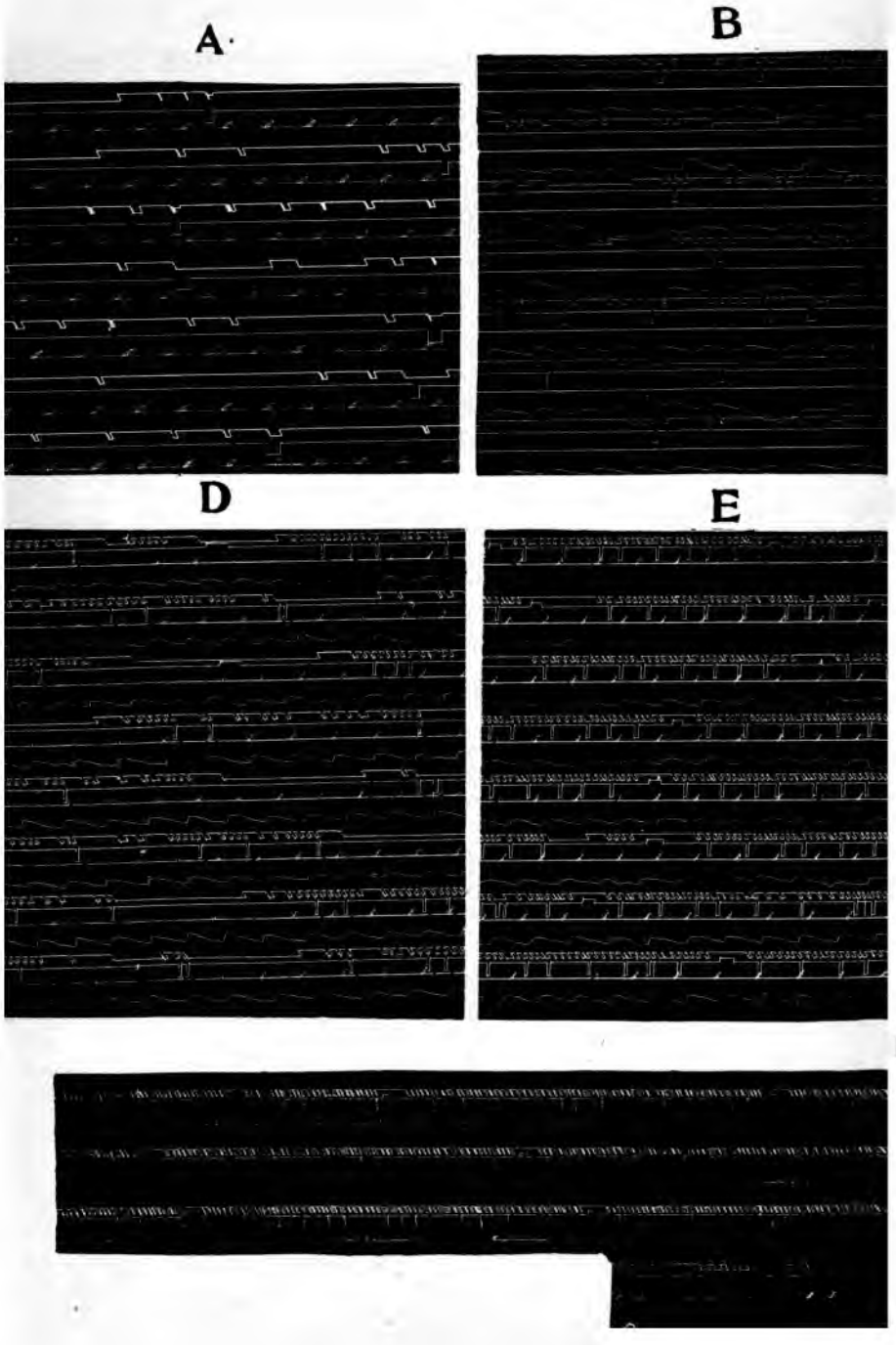
is absolutely continuous. Seventy or eighty words per minute could be written from any sort of straight copy.[1]

The above records are typical and with the introspective notes of the learners show clearly that in learning typewriting in the manner followed by our subjects there were no graded steps or stages in which habits now of this order and now of that were developed, but that all developed together. Throughout the practice there was a more or less general upward striving at once along many special and competing lines. Some of the earliest records showed some letter associations in the first stages of development, others well developed and joining to form syllable and word associations, while the easier words had already united to form phrase associations for the most common sequences of easy words.

A similar relation holds in the development of word associations. As the perfection of a letter association is dependent upon the order of letters in words and the development of a method of reacting to the words as a whole, so word associations play an important role in the development of phrase associations long before the reactions to words as such is perfected. That is to say word associations are not perfected independently of phrase associations, or before the latter begin to develop. The associations which form between the words of connected discourse help to perfect word associations even while these partially developed word associations are making possible the more economic reactions to these groups of closely connected words. In learning typewriting by our methods the elemental habits were *not* finally perfected *before* higher-order habits began to form. The development of the higher and perfection of the lower went hand in hand throughout the practice. *The lower-order habits were perfected in and through the formation of the higher, as a further development of the higher was dependent upon the final perfection of the lower.*[2] With it all went the simultaneous development of the more purely psychic habits already described (pp. 68-74).

[1] It should, however, be said that while all of Miss Carrington's records were as even and continuous as the sample shown in "H", the facts, obtained by questioning her and from certain special tests made to determine this point, show that the associations for the different words and combinations of words were not all equally perfected. The execution of some phrases and words was wholly automatic; some required a little, others more, attentive guidance, which, owing to her greater attention span, could be given, without checking the rate of writing as a whole.

[2] This confirms another statement of Bryan and Harter, namely:


A
B
D
E

It is hard to describe the exact manner in which the special associations involved in typewriting were learned. The process must be experienced and introspectively observed to be fully understood. Bryan and Harter were right when they stated "that from an early period letter and word associations make gains simultaneously *(Psy. Rev.,* Vol. VI., p. 356), and that for months the chief gain is in letter and word habits, the rate of receiving sentences in this period being mainly determined by the rate of receiving letters and words." It is also true as they state that a *full* use of the higher-order habits does not begin until the more elementary habits are well fixed, and that the usefulness of the higher depends upon the proper perfection of the lower. As they well say: "By no device is it possible to gain freedom in using the higher-order habits until the lower have been so well mastered that attention is not diverted by them." But when they base their explanation of "plateaus" on the inference that these elementary habits must be made automatic before much gain can be made in the higher habits, the length of the plateau depending upon the difficulty of making the lower-order habits sufficiently automatic to be thus used as units in a higher method of work, they were wrong. The "critical stages" in learning, where the plateaus appear, do, as a matter of fact, come in when certain lower-order habits or groups of such habits are approaching their maximum development, but these lower-order habits do not need to be perfected or further developed *before* attention can attack the higher-order habits. It normally attacks the higher-order habits long before these simpler habits even approach this stage of perfection and would continue to do so properly but for reasons later to be given (see pp. 144-146). The length of a plateau, is, therefore, *not* a measure of the difficulty of making certain special associations automatic *preparatory for use as elements in the higher-order habits,* but a measure of the time and labor required to con-

"With increased ability in taking sentences there comes, without doubt, increased ability to take isolated words and letters." (**Psy. Rev.,** Vol. VI, p. 358). They also found that more mistakes were made in receiving disconnected letters than in receiving, at a much more rapid rate, letters forming words, more mistakes made in receiving disconnected words than in receiving, at a still higher rate, connected discourse—that is, "gain in speed, made possible by adding mastery of the higher language habits to mastery of the lower, leads to greater accuracy in detail." The natural and economic order of learning typewriting is to let the specific habits perfect each other.

It is also interesting in this connection to refer to the learner's inability to locate single letters, shown in our memory tests (see p. 77), where their location as part of a word was easy enough.

quer certain difficulties encountered in the practice when these special habits are being finally perfected, difficulties which stop the development of *all* orders of habits in process of formation at the time. The elementary associations are *not* being developed, and *very rarely* further perfected during the plateau practices. *No real progress is being made* though changes important for future progress are taking place during a part of the plateau practice. The time is taken up with overcoming the special difficulties incident to that stage of advancement and to getting rid of the evil effects of the mistakes which the final perfection of the special associations naturally brings on. As soon as these are overcome and attention is again properly applied to the work *all orders of habits* begin again to develop. A description of the difficulties met with at these definite levels of advancement and their relation to the variations in our curves must be considered later (see discussion, "critical stages" p. 144-8, below). It is evident from what has here been said that we must look elsewhere than to the theory which Bryan and Harter proposed for an explanation of our plateaus.

B. HOW SPECIAL TYPEWRITING HABITS NORMALLY GROW AND DEVELOP.

While it is true as has just been shown, that habits of all orders develop simultaneously, it must not be inferred that all are making steady advance at the same instant. All learning curves that have been plotted, including our own, show that equal amounts of practice do not always give equal results as judged by the criterion "ability to do." In proportion as the measure of progress is accurate the amount of gain seems to be uneven and irregular. To what is this irregularity due? Was the development of each of the special habits involved in typewriting like the general progress of the learners, uneven and irregular, or once begun steadily continuous?

Our facts warrant an answer in favor of the first alternative. That is to say the special habits involved in the mastery of typewriting, though all developing together, are not actually driven abreast. Their manner of growth is something like the movement of a flock of sheep along a country road. The whole flock moves forward, now faster and now slower, while now this and now that particular sheep pushes ahead of the rest. So in the development of these special associations, there is general improvement along many special lines at once; all associations

involved are making progress almost from the first, but the gain is not steady, nor is it equal in various directions. It is in the matter of making new adaptations and short cuts in the line of each individual association that the irregularity comes in. There is what might be called a friendly rivalry among the various special associations developing at the moment. Progress is made along so many special lines that many opportunities for adaptation are presented. The learner's attention moves about over this array of improvement possibilities, causing an adaptation to be made, now in this, now in that department of the work as alternately focused on the different phases of the work. Now this, now that association is pushed ahead of the rest in its development, the ones not specially attended to being practiced on a lower and more automatic plane because they lack the considerable degree of attention needed to practice them in the highest way. It is, therefore, the particular distribution and use made of attention and the resultant adaptations secured that makes the development of the special habits, like the general progress in learning, uneven and irregular. One of the most common general observations revealed by the notes was the frequent relapses in the realm of the several special association developing; there were many periods in the practice when the learner's skill in one or more special departments of the work seemed to go backward instead of forward because of the particular use made of attention at the time.

C. HOW NEW ADAPTATIONS OR FORWARD STEPS IN LEARNING ARE MADE.

In a previous section it was pointed out that learning typewriting consisted in the acquisition of a hierarchy of psychophysical habits formed and developed in a special way. From the mass of old and familiar associations and activities, called into use by the earliest writing, there comes to be formed by a process of elimination and reorganization the first circuitous methods of writing used. By a definite but intricate process of "short circuiting" this earliest step-by-step method of writing is sheared of many accessories; the first associations formed are simplified, refined and reorganized into new associations or methods of writing which enable the learners to do the work in an always more direct and economical way. As the first elemental habits are being perfected they are reorganized into higher and more economical habits of work, of which new groupings they

become the elemental parts and into which their identity is gradually merged as these higher habits or groupings are in turn worked over into yet higher mental complexes by processes of "short circuiting" similar to those that occurred in their own formation. Progress in typewriting is brought about (a) by the gradual perfection of these special habits, and (b) by the new adaptations or short cuts in method that are made as higher-order habits are formed. The special introspective notes of our learners, purporting to give a complete analysis of the learning consciousness in all stages of advancement, revealed two important facts about this "short circuiting." (1) That it was on the good days and during the good periods of writing, when the learners were fully warmed up, feeling good, and putting all available energy into the work, that they found themselves making new adaptations or taking a forward step in the learning. (2) That all new adaptations or short cuts in method were unconsciously made, i. e., fallen into by the learners quite unintentionally, on the good days, while practicing under strain. The importance of these facts for learning demands that they be treated more in detail.

1. Role Played by Effort in Learning Typewriting.

Bryan and Harter in their study of telegraphy, found that years of daily practice in receiving telegraphic messages at ordinary rates would not bring a man to his maximum ability to receive. While men whose receiving curve had been upon a level for years frequently rose to a far higher rate when forced to do so in order to secure or hold a position requiring the higher skill. Their conclusion was that "it is intense effort that educates" and they add "that one reason why sixty-five per cent of those who begin to study telegraphy get discouraged and quit when they reach the first plateau is that they do not make the painful effort necessary to become experts." Johnson, in his Researches in Practice and Habit *(Yale Psychological Studies,* Vol. VI, 1898, p. 83), writes: "Every advancement either in mental quickness or muscular activity requires a certain effort, depending upon the stage of development already attained. . . . . . The 'plateaus' mentioned by Bryan in the habit curve would seem rather to indicate resting periods in the effort.[1] If the subject can be induced to sustain the same effort

[1] Compare also Swift's study, The Acquisition of Skill in Typewriting, **Psy. Bull.**, Vol. I, p. 300, and the studies by E. Meumann, Uber

day by day, there would be no 'plateaus' in the habit curve."

The present study has not only verified the conclusions of these investigators by showing that *less effort was actually put into the work at all those stages of practice where little or no improvement was made* (see pp. 161, below), but has revealed the particular role which effort plays in learning typewriting. It was clearly determined that a learner must work with a "do-or-die" attitude to make new adaptations or take a forward step in the learning. Relaxation of attention or effort and fatigue not only keeps a learner from practicing the newest and most economical habits he has learned, but keeps him from making new adaptations because he is forced under such conditions to write in a more primitive way than he is capable of when in first class condition and doing his best. To prevent arrest and insure the most rapid progress, attention must be kept sharply focussed on the details of the work and continually pushed out on the frontier where new adaptations in method can be laid hold of.

This fact will be made clearer by a few typical quotations from the notes. During one of his special practice periods, X wrote: "I am coming to believe that great effort is required to make the best progress in the work. The tendency to lag and revert to older and more primitive methods of writing is very strong and must be overcome. Only in moments of extreme effort am I able to make innovations or lay hold of higher and better ways of doing the work. I very suddenly catch myself doing the writing in a more economical way. In another week I find that I have improved on my method again and so it goes, but in no case have I found that the adjustment was purposely made. I was simply pushed into the better way by the strong desire to do my best." On another day, after describing the tendency to see all the letters when it was no longer necessary, he wrote: "When I push myself and try my best, many of these detailed locations with the eye drop out and the writing is done on a higher plane. The eternal problem in learning is, to know how fast to go. Great effort wrongly and carelessly applied, causes a breakdown, too little effort lets you slip into

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Okonomie und Technik des Lernens, Leipzig, 1903, pp. 100-101, and Uber Einige Grundfragen der Psychologie der Ubungsphanomene im Bereich des Gedachtnisses, **Archiv. fur die Gesamte Psychologie,** Vol. IV, 1904, p. 21. See also the opinion of Senator Stanford on the training of race horses quoted by Bryan, **Psy. Rev.,** Vol. IV, p. 51.

an easier and more primitive way of writing. In either case the improvement stops. You either practice in error or settle down to a low plane of writing quite satisfied with yourself when you should be pushing yourself onto a higher plane." After being asked to make observations and carefully describe all the mental processes involved in taking a forward step in the writing, Z wrote in his special notes: "I can make the movements much faster now than I can move my eyes to the individual keys. This makes the tendency to short circuit in the matter of locating the individual letters very strong. The eyes no longer move in the spelling curve, that is, from one letter to another as the word is spelled out on the keys. They only fixate the letters that must be seen, to be properly struck. This 'short circuiting' only takes place, however, when I am pushing myself very hard, for the tendency to wait to see all the keys is very strong. Only when I am going so fast that this is impossible is the new method of reaching the keys laid hold of and used."

This brings us to the consideration of a second fact which shows more clearly still the specific role played by effort in learning. It was observed by the learners that the older and more elemental habits used in the earlier stages of writing tended strongly to persist and force themselves upon the learners long after they had been superceded by higher-order habits. At every lapse in attention or relaxation of effort, the older habits stepped forward, as it were, and assumed control, thereby tending to perpetuate themselves. Only when a high degree of efficient effort was being persistently applied, only when the learners were urging themselves forward so hard that these outgrown habits had no chance to be used was attention forced to lay hold of the higher and more economical methods of work.[1]

An illustration or two will make the point clear. In describing how the spelling was done at a certain stage of the writing, X wrote: "The actual spelling is in all stages of dropping out. In strange new words it is strongest and nearest to the original type and extends all the way down the scale to where there is a mere weak, blurred motorization for the whole word, where, at times, one 'motor-nod' serves for a little word, at other times for a syllable. The natural tendency is to put in

[1] This persistency of habits or tendency to resistance when being superseded by others should not be confused with the frequent lapses which occurred in all departments of the work. There was a constant use of the lower-order habits on the bad days and during an off period, but these relapses are a different phenomenon.

as many of the old steps as possible. The old time spelling is no longer needed and is superseded by this new spelling process which sets off the whole word at once. This is changing, too, and is very hard to describe. But the tendency to continue the old process of spelling a word, letter by letter, which has long been outgrown, and for which there no longer is time, is very strong. It requires special effort and continual care to keep from dropping into these older and slower methods of writing. You only outgrow them when you sprint sufficiently to leave them behind, or go so fast that they cannot come in."

Other typical quotations illustrating the persistency of older habits or methods of work are the following: "I sometimes write a word, more often part of a word, unconsciously, that is, without any of the conscious direction that enables me to prove the work. I nearly always notice this omission and want to wait and spell the word out or prove it before I go on" (X, Mar. 27). "Noticed one case today where a certain letter was made without conscious direction of the individual movement. But the habit of consciously directing each movement is so strong that this direction came in *after* the letter had been struck. I caught myself waiting and actually going through the older process *after* the letter had been struck instead of going on to the next move as I was free to do. This sort of thing often occurs," (Apr. 2). On another day he wrote: "In many cases the mere sight or idea of a letter is sufficient to produce the right movement. But in these cases the consciousness of the feel of the movement comes later. This checks the work unnecessarily for I often catch myself waiting for the 'recognition feel' which, instead of going *with* the move as it did, now tags along *behind.* The best results are attained when attention omits these automatic steps as fast as possible."

2. Part Played by Consciousness in Learning Typewriting.

A second significant fact about the learning is, as we have said, that all adaptations and short cuts in method were unconsciously made, that is, fallen into by the learners quite unintentionally on the good days while practicing under strain. The learners suddenly noticed that they were doing certain parts of the work in a new and better way, then purposely adopted it in the future. In learning to "short circuit" the first elaborate methods of making the letters, in developing syllable and word

associations and associations between the words of compact phrases or clauses, in making improvements in mental spelling, in learning to get and hold the copy more economically, in learning to attend and economize effort, etc., the new adaptations or forward steps were all unconsciously made. It seemed to be the strong desire to write with the utmost speed, strengthened in some cases by the thought of the value or worth of the experiment, that pushed the learners into these new and more economical ways of writing.

Quotations from the notes might be multiplied almost indefinitely. A few representative passages will indicate the role which consciousness played in the taking of these forward steps.[1]

"I caught myself this morning," wrote X, "letting my finger stay on a key last struck with that hand and remembering where it was while the other made several letters. I find that this helps a great deal in locating the next letter or letters to be struck with that hand. The next letter may be the same as the last one made with that hand, the one either above, below, or at its side. It can, therefore, be more easily located from that position. This adaptation was not premeditated or planned. I unexpectedly caught myself doing the writing in this way after I had been writing some time. I was simply intent on getting to the keys as rapidly as possible when my fingers developed this way of finding them. I also caught myself today locating many letters with reference to the ones previously struck instead of going back to the little fingers as reference. This, too, was fallen into quite unconsciously. As near as I could tell, attention of itself began to move in this new way, pushed ahead by the one desire of getting the fingers to the several keys as rapidly as possible. Several times when I wanted "r" for example, I caught myself going to the "t" direct, which I can now locate directly by attending to the motor-tactual 'feel' of the movement for striking it, then striking the r at its side. This is a quicker way of getting the "r" than locating it in the old way via. q, w and e.

Fourteen days later he wrote: "I have unconsciously learned to let my fingers remain on the last key struck and remember where each finger is. This helps me greatly in locating the keys and seems to keep me oriented better on the keyboard. It seems to increase my attention span and to bring about a higher mode of attentive direction. All I know about the way this new adaptation was made is that I unexpectedly noticed that I was thus letting my fingers remain on the keys and keeping enough attention on them to remember where they were, so that I could proceed directly from there to the next key. As soon as I noticed it I recognized its advantage and tried to purposely adopt it, but found that I must more or less let it work itself out. When I tried to do it consciously I gave too much attention to it

[1] The whole problem of unconscious learning is here raised. Are all adaptations and the so-called inventions in learning made as in typewriting simply by getting and keeping the learner in close contact with the task so he will stumble onto the new and more direct way quite unconsciously, or does consciousness play a more important role in taking the forward step than our results show? If so, what role does it play? The problem might be approached, it would seem, by a careful introspective analysis of the "Reasoning Consciousness", the consciousness accompanying learning to solve a problem or working a puzzle. It would be important to know more about the specific role which consciousness plays.

and other things got away. Making these forward steps seems to be the natural consequence of careful practice under strain."

On another day he wrote: "In locating the letters I do not have any visual image of the keyboard at all. I find that I can write more easily if I keep my eyes firmly fixed on the letters of the copy while I write them, and my attention on the keyboard. I simply think where each letter is, which means that there is a movement of attention over the course to be taken by the finger in striking the proper key. If the position of the key is easy with reference to the previous letter, I can go to it directly and easily. If not I have to fumble over a longer and more detailed path. I find that I unconsciously adopt all sorts of means to help me in getting my fingers to the individual keys. I noticed a case today where I had my left forefinger on the "t" key when I had to strike the "y" (a very hard letter to locate) with the other hand. I immediately felt one key over to the "y" with my left forefinger and struck the "y" key, thus located, with the right forefinger directly. It saved the long round about way of locating the "y" usually employed. The attention of itself moved in this way quick as a flash and I had completely finished the process and was reaching for the next key when I noticed what I had done and stopped writing to make a note of it."

On another day he wrote: "There has been a tendency to turn the eyes away from the copy to the writing to see whether or not it was right. This was fallen into because of the tendency to reach for the keys directly instead of feeling my way to them in the old way. I wanted to test the correctness. This change, I am sure, took some of my attention from the process of directing the movements and keeping oriented on the keyboard. Today I fell into the habit again of keeping my eyes closely fixated on the copy which again throws my main attention on directing the individual movements of my hands. This brought a sort of warming up and enabled me to go on with these movements executing them in an almost unbroken series which was distinctly pleasurable. I seemed to feel the associations and the assurance of correctness growing. I found myself gradually feeling my way more and more directly to the different keys and so building up connections between the order of the letters in a word, and the position of their letters on the keyboard, all of which was very different from yesterday, because my whole attention was now kept on just this direction and motor-tactual image, made possible because I now make all the testing motor so that attention is on only one sort of work. The change was not premeditated in any sense. I simply happened to notice that I was doing it in this way and how much better it was than the way I did it on previous days, so purposely adopted it. It became a pleasure to feel my way over the keyboard testing correctness by touch rather than by looking at what I had written."

At a still later stage we read in his special notes: "If a break in the writing occurs from any cause, the feeling tone changes at once. Your control over the spelling and copy, and your ability to recognize directly and easily the rightness of the movements is interfered with. You no longer can go directly and surely to the next key; you must resort to an older, more roundabout way of locating the keys, until the direct feel is again built up. In this relearning all sorts of temporary helps are used which assist motor-tactual recognition. All sorts of ways of testing the right location of the key to be struck are used. But no more than are required. As soon as the movement can be made direct and its correctness recognized by attention to its 'feel', these old helps are discarded. These emergency helps are never alike. New and better ones are used from time to time as conditions at the time require. If one was not trying to see just how the work was done, the kind of helps invented and used as well as the fact that they were employed, would never rise into consciousness at all."

At the close of one of his daily tests, Z said: "I have been surprised at how little control I have over the way attention works. We may do much towards keeping it concentrated on the work, but all improvements in method are unconsciously made. Attention of itself

lays hold of the opportunities presented for making short cuts. I have often observed that improvements are always made before I notice their need or think of doing it that way."

We are now in position to see why little or no improvement is made when attention and effort are relaxed. A lapse in attention and effort means that fewer adaptations are made. The learner settles down to more primitive methods of work, writing on a low plane when closer attention and increased effort would mean new adaptations, rapid improvement, and the development of more advanced methods of work. The fact that these lapses in attention and effort were so largely beyond the learner's control, and the further fact that the learning was unconscious, the organism adapting itself to the conditions presented with so little help from consciousness, emphasizes again the importance of hygiene for learning. It is not what the learner would like to do that determines his rate of progress in learning, but what his mental and physical conditions at the time will let him do. Learning typewriting is something like mowing a field. The farmer takes out his machine to cut the grass. All he can do is to keep his machine in perfect condition and properly and vigorously applied to the work. The machine does all the rest. It does its own work in its own way. How well the farmer succeeds depends (1) upon the nature and condition of his machine, and (2) upon how strenuously and well he keeps it applied to the work. So in learning typewriting. The learner begins his task of learning to use the typewriter. How rapidly he improves depends (1) upon the learner himself and upon the mental and physical condition of his organism, and (2) upon how carefully and strenuously he keeps himself applied to his task. The best thing a learner can do is to keep himself in perfect condition and strenuously but properly applied to the work, the organism will do the rest.

D. HOW SPECIAL TYPEWRITING HABITS ARE PERFECTED.

The most obvious explanation of the general form of the learning curve for any complex process of learning like typewriting is, that it is really the summed result of a number of elemental habits all of which show the same typical rapid gain at the beginning, where there are many possibilities for "short circuiting", and slow gain at the end, where all progress must come from a further perfection of the habits as such. This our

observations abundantly justify, but it is not the sole reason for the slow advance in the later stages of progress. Another is to be found in the fact, also sufficiently demonstrated by what has gone before, that gain in skill in typewriting is a process of progressive organization and co-ordination of simple activities, and there is every reason to think that such a process will itself go on more readily with simple than with more complex elements, so that in this respect also we should look for a regular decline in the rate of gain as practice continues. Still a third factor, and *one very important for learning,* is to be found in the relation of these nearly automatic processes to attention. As has already been pointed out in preceding sections (see especially pp. 33, 40-42, 57-58, 59-62, 66-67), these processes need a minimum of oversight for a very long time even after they seem completely self-regulative. In other words habits are perfected or sink to the realm of the unconscious *very gradually.* If we might speak of their final perfection or dropping out of consciousness as dying, they die hard. At the same time they have become extremely hard to hold in attention because they are so nearly automatic. In the early stages of their development, where many adaptations and short-cuts in method were possible, they more naturally compelled attention because progress was rapid and easy. Later when most short-cuts have been made, when advancement depends upon the perfection of the associations already formed, and when progress is slow and the chances for gain reduced to a minimum, attention tends *naturally* to drift to other things, making those stages in the learning where a particular association or group of special associations is being finally perfected distinctly "critical" in nature. The full significance of this fact for learning will be discussed later, but it may be remarked in passing, that the help of a skillful teacher is especially needed at these "critical stages." (1) To encourage the faint-hearted learner; (2) to see that he attends to all details until they are mastered.

E. THE GENERAL COURSE OF THE LEARNING CURVES EXPLAINED.

After what has been said our explanation of the general features of our curves can be brief. The first rapid and continuous rise is due to the fact that the learner is making progress along many different lines at once. Rapid strides of improvement are possible and made simultaneously in every department

of the work. The learner is not only forming and perfecting letter assocciations but syllable, word and phrase associations as well. He is simultaneously improving his method of dealing with every problem that the writing presents; locating the keys, directing and controlling his fingers, "spelling" or initiating the movements, getting his copy, learning to deal with special difficulties, learning to keep attention more closely and economically applied to the work, etc. The curves will rise rapidly and continuously so long as many of these possibilities of improvement exist. As they grow less numerous the rate of gain will likewise decline until, as still more skill is acquired, a state is reached where most adaptations or short cuts in method have been made; fewer special habits remain to be developed; fewer adaptations are possible. Those possible have become harder and harder to make, because they must be made in the realm of higher habits where the learner has had less experience. Every man has had experience with the first stages of learning, but little with the later stages because most people touch lightly many things and are masters of nothing. There being now fewer adaptations to make and those possible being harder and harder to make, and the process of finally perfecting all the special associations being so gradual and slow, the learning curve becomes, as the expert stage is approached, almost horizontal. In the later stages of learning the sole gain must come from an occasional adaptation and from a further perfection of the present habits and methods of work.

VI.

PHENOMENA INFLUENCING LEARNING AND RATE OF WORK.

Thus far we have dealt entirely with what might be called the progressive changes which the learning or practice produced, with the formation and development of typewriting habits of every kind and grade, but have said nothing about the factors which conditioned their development and growth. We have talked as if learning went on in a perfectly simple, straightforward way. But learning to use a typewriter is by no means a simple or steadily continuous procedure as our learning curves show. Many things help to make progress in learning unsteady,

and not the least of our tasks in presenting our results will be the treatment of the factors which operated in producing our *actual curves.*

A. SOME OBJECTIVE FACTORS THAT INFLUENCE LEARNING AND RATE OF WORK.

The amount written on any particular day is, of course, the resultant of many co-operating influences, some external and some internal, some tending to increase the score, some tending to diminish it; but their method of combination is not always one of simple addition or subtraction, and in many cases defies analysis. Objective difficulties in any part of the work were found to sometimes attract attention so suddenly and strongly as to break up completely the typewriting psychosis for the day. Any long, hard or unfamiliar word takes extra attention and must be written in a more primitive way than the average run of words. When one of these difficult words is run onto in the course of the writing, the learner's orientation on the keyboard and special "set" of mind is lost and cannot instantly be regained. If they occur often their effects accumulate and the score for the day will be appreciably lowered. On a certain day the words "psychological" and "physiological" often occurred in the copy Y was writing. His notes clearly showed that the mental disturbance caused by these long and difficult words was responsible for the low score that day. But such an interruption may be caused by other things than the copy. A number of cases were described in the daily notes where changing the paper in the machine, reversing the ribbon, changing the tension of the keys, changing the article copied, and in the later stages of the S. M. practice, a particularly interesting bit of copy had such an effect on attention. One day Y had been marking off a tennis court and failed to get all the lime dust off his fingers. The sticky feeling and the distractions set up by wondering whether this would materially affect his score and speculating about the particular kind of effect it was having so interfered with the working of his attention as to materially diminish his score for the day.[1] The remark of Miss Carrington, already quoted, "If I am in a contest and once think, 'I wonder how Miss —— is getting along,' I know I have lost,"

[1] It probably also influenced his touch discrimination though this was not mentioned in the analysis of the disturbance given in his note for the day.

indicates how much a writer's score is interfered with by such distractions, and introduces us at once to the more important group of difficulties or disturbances of subjective origin.

B. SOME SUBJECTIVE FACTORS THAT INFLUENCE LEARNING AND RATE OF WORK.

1. Relearning and Warming Up.

It is a common experience in many sorts of mental and physical work to find a short period of "warming up" necessary before the best work can be done. The cause of this improvement is doubtless quite complex and may vary considerably from one sort of work to another. We do not propose to offer a full analysis of it; but two factors came out in our work on typewriting with some distinctness. It will be convenient to treat them separately, though they operate simultaneously and doubtless are very closely connected. We shall call the first "Relearning", reserving the term "Warming Up" to cover an improvement in the general psycho-physical condition of the learner which shows itself on the one side in better attention and general mental and motor efficiency and on the other in increased rapidity of circulation.

(a) The Daily Relearning.—Memory as everyone knows is basic for acquisition and learning. The reason some subjects improve so slowly is that it takes them most of the day to relearn what they forget over night. A learner's progress, therefore, depends as much upon how well the effects of practice can be retained and on how quickly and easily lapsed acquisitions can be revived, as upon the amount learned each day. Memory permanency and the factors which influence retention, have been studied, but their relation to acquisition has, to my knowledge, not been touched upon, save indirectly by Leuba, Lindley, Specht and those studies by Kraepelin and his pupils which seek to determine the most economic periods of work and rest for different kinds of work.[1] We have already had occasion to speak of the importance for learning of proper intervals of work and rest (see pp. 83-84). The daily relearning is closely

[1] See especially Kraepelin's **Psychologische Arbeiten**, Vol. III, pp. 482-534, Vol. IV, pp. 554-556, and Leuba's study, "An Experiment in Learning to Make Hand Movements", **Psy. Rev.**, Vol. XII, Nov., 1905, pp. 361-369, **Archiv fur die Gesamte Psychologie**, Vol. III, 1904, pp. 1-32, article by Specht.

related to them and must be taken into account in every serious study of learning.[1]

That an actual daily relearning occurred was shown by a variety of facts. A comparison of the amounts written in the several minutes of all the tests revealed the fact that for all subjects the rate of writing increased rapidly for the first five or six minutes of the T. M. (ten minute) tests and slowly for some ten or twelve minutes in the S. M. (thirty minute) tests, (see Fig. VI, below). The drum records showed that for the middle or last part of the writing of almost any test the strokes came closer together on the records and indicated by their arrangement that habits of a higher order were used.

That a part of this increase in efficiency was due to a daily relearning was shown by the observations of the learners which disclosed the fact that none of the associations involved in typewriting worked as easily or readily upon first beginning to write each day as afterwards. The newer adaptations and latest short cuts in method could not be used immediately upon beginning to write. All associations used had to be revived each day or exercised for a time before they worked easily and perfectly. As Y expressed it (May 10): "It seems to be true for every day that during the first five minutes or so of the writing I cannot go at an average rate. This was particularly noticeable again today. The main difficulty in this seems to be the fact that I cannot recognize positions on the keyboard. I have to fumble around to get my fingers placed, and when I do have them correctly placed, it often takes some time to decide that they are thus rightly placed. Likewise, when they go wrong, I do not notice it and hesitate to decide where to strike for a key I want. I can find nothing in it but this—the slowness and absence of ready recognition. The "warming up" which occurs as the practice continues seems to consist simply in a rapid disappearance of this difficulty. As I go on writing things seem to clear up on the keyboard, the fingers begin to find their places readily, I know when they are rightly or wrongly placed at once and I do not hesitate any more in directing them." Other typical descriptions of this daily relearning are the following: "In first beginning to write each day," wrote Z, "I

[1] The importance of the relearning and the diminished effect of practice after a certain optimum amount, as well as the advantage of properly distributed repetitions, was shown by Ebbinghaus' early experiments (see Uber das Gadachtniss, Leipzig, 1885, pp. 83, 122).

often notice a greater difficulty for the first few minutes in finding the keys. There is a decided 'warming up' in this respect." On another day he wrote: "I noticed in beginning to write today that the movements of the fingers were very inaccurate and hard to control and required much more conscious direction than they did later on in the test."

X observed that the memory of the muscular "feel" of the semi-automatic movements, which, in the letter association stage of the T. M. writing, directed the fingers and hands, lasted but a very short time. When this association was being formed the motor-tactual image for the movements was lost altogether over night and had often to be revived with each removal of the hands from the keyboard. Touch recognition had to be newly acquired each day until a high degree of automatism had been attained. On Dec. 10, he wrote in his notes: "Have noticed for some time that when I first begin to write, I do much more detailed directing with the attention, and put in more steps in getting my fingers to the keys than I do when I have written a while I cannot rely on the "feel" of the movements directly for guidance, but must assure myself by touching some of the intervening keys. I cannot write by the newest methods but must use an earlier, surer method of getting my fingers to the keys. This is often necessary when I stop just for a minute to move back the carriage or have greatly changed the position of my hand."

What the daily relearning includes depends upon the method of writing and stage of development reached. After making careful tests in the last days of his practice sentence writing (S. M.), in order to see what letters it was still necessary to fixate with the eyes, X wrote: "After a long pause, and on succeeding days when first beginning to write, I use my eyes on all the letters. After a little practice, the eyes are only used in locating a few of the keys." In his T. M. notes he wrote: "Upon beginning a test and after a break in the work most letters require the 'feel' of the direct movement to be built up anew by the surer and more roundabout method of locating the letters, employed in an earlier stage. The motor-tactual image cannot be depended upon for guidance during the first minutes of a test."

No attempt was made to determine the amount of loss incurred by this daily forgetting or to ascertain the individual differences in this regard. It was only determined that such

relearning occurred and that it was important for acquisition, a matter to which we shall later return.

(b) The Warming Up.—Curves drawn on the basis of the average amount of work done each minute in all the tests, showed for the T. M. practice, as we have said, a rapid and continuous rise for the first five or six minutes of the test (heavy line of section A, Fig. VI), followed by a decline the sixth, seventh and eighth minutes, and a second rise as the end of the test was

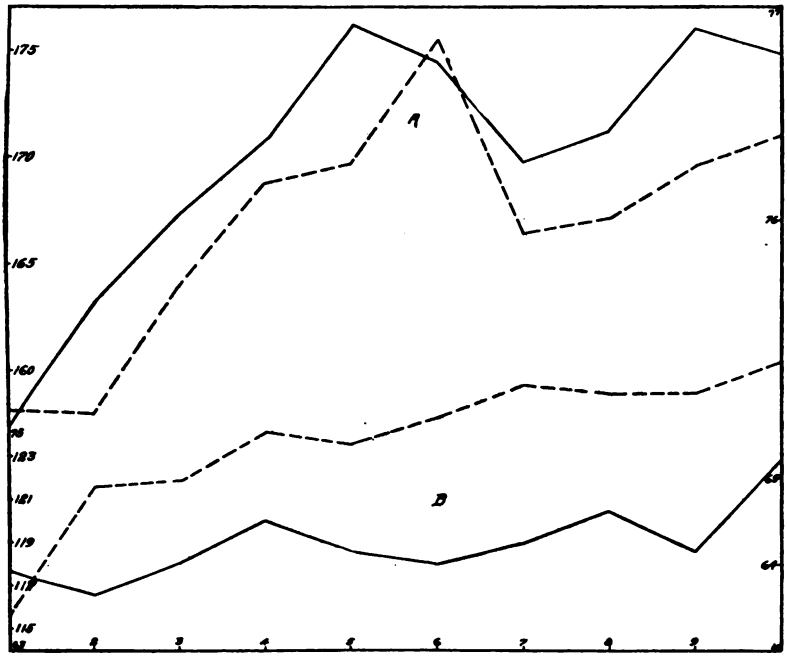


FIG. VI.

Fig. VI, represents curves drawn on the basis of the average number of strokes made on the machine each minute for all the tests, the heavy lines, and the average pulse rate for each minute for all the tests, the dotted lines.

Part "A" of the figure shows the curves for the T. M. learning of Y and represents 130 practices. "B" presents the curves for the S. M. practice of Z and represents 86 practices. The successive minutes of the tests are shown (1-10) along the horizontal axis. The pulse rate is shown by the figures on the vertical axis to the right. The amount of work done (in strokes) is shown on the vertical axis at the left.

To set in better contrast the salient features of the curves and keep them within bounds the curves in the two sections, "A" and "B", had to be drawn on a different scale.

approached.[1] The curves for the S. M. practice show that in these longer tests (it will be remembered that the S. M. tests were thirty minutes long, the T. M. tests but ten), almost no "warming up" occurred and that it was distributed over a longer period of time (heavy line of section B, Fig. VI).

Pulse curves[2] drawn on the basis of the average pulse rate each minute for all the tests (dotted lines in Fig. VI) showed that with the warming up, or increase in efficiency, there always went an increase in pulse rate. In every case the pulse curves follow rather faithfully the work or efficiency curves. Compare section A, Fig. X, p. 117, and Figs. XII, XIII and XIV, pp. 128-129, below).

To understand this increased efficiency we must consider the following facts. On the mental side we have: (1) The daily relearning already described. (2) The warming up or development of a typewriting psychosis, the acquisition of a helpful "set" of mind which gave a sort of bent or momentum to attention. On the physical side we have: (1) The actual activity involved in the practice. (2) The increased circulation or general physiological "limbering up", revealed by the rise in pulse. It was found, that when the learners first began to write each day, their attention did not work so easily or economically as it did afterwards. It could not be applied so effectively to the details of the work. By no manner of means could the learners make it behave as it naturally did of itself after the "warming up" had occurred. As one of the S. M. learners expressed it: "When my eyes work ahead of my hands, as is now the case, the tendency is for the hands to strike too far ahead in the word, that is, go with the eyes when insufficient attention is given to the work. The eyes are now running ahead in this way as is also a certain process of ideation that used to be the 'spelling'. A certain distribution of attention is required

[1] The reason why Y's efficiency curve given in the figure does not show a rise the last minute is the lack of "Schlusz Antrieb" in his plateau practice, June 19 to July 29. If the records for these days are excluded his curve shows a final rise. See Fig. XII, p. 128.

[2] It will be recalled that a pulse tracing was recorded with the record of the writing on the drum in the hope that the pulse would give some indication of whatever fluctuations in attention and effort might occur. From these records the pulse rate was determined for each successive minute of every test. The pulse curves correlated with the efficiency curves in this and the following figures are based in each case on the average working pulse for the several minutes. We may assume without hesitation that these pulse and efficiency curves represent the action of a constant influence. See note, appendix to this study, p. 182.

to make this method of directing the movements go on to advantage. Any distraction upsets it, anything that tends to occupy the attention or to interfere with my control over it makes trouble. When I get warmed up my attention is properly divided, each part of the work gets its share of attentive direction. I am then able to so manipulate and control attention that easy and fast writing results. I am able to keep other things out of consciousness by keeping my mind wholly focused on the details of the work. It seems as though, in these periods, a set of mind is developed that makes for quick and easy work. I don't know how I get it but know that my attention is kept focussed on the work, that it is properly divided, and that it works more of itself."

As this quotation suggests one of the important facts about this increase in efficiency is its spontaneity. It seemed to be wholly beyond the learner's control; it came of itself, if it came at all, and could neither be hurried nor controlled. On June 10, Y wrote: "Noticed a distinct warming up again today. For the first minute or so my orientation on the keyboard did not clear up. I could not readily decide in each case whether my fingers were placed correctly or not. The 'clearing up' seemed very abrupt but I could see no cause for the sudden increase in efficiency." On another day (June 1) he wrote: "For the first minute or two I could not get started at all, could tell nothing about where my fingers were, no recognition of errors or correctness was present. I felt utterly lost on the keyboard. I got started fast very suddenly. The recognition, absent at first, came in all at once, after which the writing went easy and fast." On May 13, Z wrote: "Came out of the bad period experienced when I first began to write, by waiting before the word or letters long enough for the right association to come up. At first these associations had to be dragged in, in the roundabout way I employed in building them up in the earlier stages. They soon came up more easily. With this went a feeling of pleasure and satisfaction, which, for one thing, made me willing and satisfied to go slow enough to give time for the associations to come up. I have learned that you can't hurry the associations or force attention much, if at all. When you try it, you go to pieces and lose control."

Another fact that should be mentioned is that a distinct warming up did not occur every day as the curves might sug-

gest. On some days the learners seemed to be "warmed up" when they began to write or got warmed up very soon after starting. They could at once begin writing at a maximum rate and keep it up throughout the test. On other days no "warming up" seemed to occur or if it did it was so slight that it was barely noticeable and came in only towards the end of the test.[1] But such days were the exception or our curves would tell a different story.

Summarizing our facts on the relearning and warming up we find going with the increased efficiency revealed by our curves: (1) A daily relearning or revival of the associations learned, (2) the acquisition of a favorable "set" of mind or development of a typewriting psychosis, (3) a sort of joint effect of these changed mental conditions, the disappearance of many former difficulties. The learner suddenly gains better control of every detail of the work; he feels as if he had become relieved of the care of many details; the writing becomes noticeably easier all at once; the keyboard suddenly clears up; difficulties encountered in the first part of the test suddenly disappear; the fingers become limber and of themselves do more towards finding the keys; attention works more spontaneously, etc. That with these changes in consciousness there should always go a marked increase in blood supply as shown by the correlation between the pulse and efficiency curves is as significant as it is interesting. It suggests an increase in spontaneous attention or effort, a sort of physiological limbering up, a close relation between the revival of the growing associations and the nutritive changes set up by the increase in blood supply.

(c) Significance, for Acquisition, of the Daily Relearning and Warming Up.—The fact that an actual daily relearning or revival of the newly formed associations occurs during the early part of a test gives a scientific basis for the generally felt need of starting any activity, mental or physical, slowly and working rather leisurely until all the associations involved have been

[1] This would seem to be due to the irregular fluctuation in efficiency during the course of a day found by Marsh. (**Archives of Philosophy, Psychology and Scientific Method,** Columbia Contributions to Philosophy and Psychology, July, 1906, pp. 1-97). On the days when the learners were at their "top notch" of efficiency and warmed up to begin with, the test found them at the crest of one of these daily efficiency waves; on the days when no warming up seemed to help them, at a trough in the daily efficiency wave, for the whole series of tests these would balance each other and give us the normal phenomenon of warming up as shown by our curve.

fully revived. When we add the fact that the most automatic habits which the learner has acquired must be exercised for a time before they will work perfectly, and that a typewriting psychosis, or favorable "set" of mind, must be developed, before the work can be done on the highest plane the learner has yet attained, the significance of the relearning and warming up for acquisition becomes clear. There are times when pushing ahead with a "do-or-die" attitude results in retrogression and failure to learn. Such periods occur on an off day and during the early part of a test. Upon first beginning to write the learner must go slower and carefully refresh the newly acquired associations and revive the old ones *before* he can work to advantage with a "do-or-die" attitude. If this is neglected he will push himself into his own undoing instead of onto a higher plane of work.[1] Only on the good days when all associations have been carefully revived is it profitable to "sprint." It is strenuous effort carefully applied to the details of the work when all conditions are favorable and when the learner is thoroughly warmed up and has the right psychosis for making a leap that results in new adaptations and lifts the learner out of his habitual ruts onto the higher planes of work.[2]

2. *Fluctuations in Attention and Effort.*

The most imtortant phenomenon influencing learning and rate of work and the cause of much unsteadiness in the rise of the learning curves was the fluctuations in attention and effort which occurred as the practice proceeded. It was found that the learner's *spontaneous* attention or natural efficiency varied from minute to minute of every test, from day to day and at different stages of the learning; the amount of *voluntary* attention or effort at his command varied in a similar way; and the

[1] X, who started his S. M. tests more nervously and showed the greatest initial spurt in effort, showed the slowest rate of improvement. Both Y and Z started their tests more leisurely and showed more rapid and steady improvement than did X. In his T. M. learning X's progress was more steady and rapid and his notes clearly show that he had learned to start into his tests a little more leisurely. As he one day phrased it: "Learned from watching Y and Z the value of making haste slowly."

[2] This lesson the expert has thoroughly learned (compare pp. 68-74 above), but it is a critical problem for the learner, hard to solve alone. X did not learn the practical significance of this point until in his T. M. learning. His rapid improvement in that method was largely due to the fact that he had learned **when** and **how** to try. Most learners do not of themselves learn to profit by this fact without paying dearly for their lesson.

learner's ability to direct his energies effectively, and supplement the defects of spontaneous attention by voluntary attention likewise varied in the same universal and irregular way.[1] These fluctuations, while their cause and effects cannot always be disentangled, are jointly so important for learning that they need to be fully described and their relation to acquisition carefully pointed out.

Our evidence for these variations in attention and effort is fourfold: (1) The notes of the learners, spontaneously written down each day at the close of the test. (2) The notes of the experimenter. (3) The records of the working pulse. (4) The errors made. As heretofore the observations of the learners, when verified by objective data, were made the ultimate court of appeal. The pulse curves and errors showed not only that the observations of the learners concerning the fluctuations in attention and effort were correct, but revealed additional variations of which the learners were ignorant. In our treatment of these fluctuations in attention and effort we shall first inquire into the nature and validity of some of our evidence, then describe the fluctuations themselves, stating so far as possible, their cause and influence on the learning in every case.

(a) Correlation of the Learning and Efficiency Curves with the Curves of Pulse Rate.—Perhaps the most important and significant fact brought out in the entire investigation was the close correlation between the pulse, efficiency and learning curves. For all the regular writing tests there is a higher average rise in pulse for the rises (slow and rapid) in the learning curves than for the plateaus, a higher average rise in normal pulse for the periods of rapid improvement than for periods of slow improvement or arrest. This fact is clearly shown by the data given in table III and Figs. II and XV, pp. 20, 140.

A similar correlation holds for the pulse and efficiency curves. Compare Fig. VI above, A of Fig. X, and Figs. XI, XII, XIII and XIV, pp. 117, 126, 128. During most of their course these pulse and efficiency curves go up and down together.

[1] A rather marked progressive change in the learner's attentive efficiency also occurred and was described above as learning to attend and economize effort (see pp. 73-74). This general practice effect should be carefully distinguished from the regular fluctuations here treated. The former was a part of the learning itself, the latter a condition modifying it.

TABLE III.

	Rises in Learning Curve				Plateaus in Learning Curves			
	DATE.	No. Tests Taken	Ave. Rise in Pulse.	M. V.	DATE.	No. Tests Taken	Ave. Rise in Pulse.	M. V.
V's T. M. Practice.	March 11-June 19	96 days	8.21	1.90	June 19-July 29...	32 days	6.77	2.01
	May 2-June 19.....	48 days	8.30	1.82	June 24-July 10...	10 days	5.44	2.07
Z's S. M. Practice.	March 20-Apr. 14	16 days	7.80	2.50	May 27-June 22...	20 days	6.81	1.25
	April 11-27.....	16 days	7.12	1.59				
	May 6-26.....	18 days	7.35	1.56	June 16-22.....	6 days	5.80	1.06
X's S. M. Practice.	March 17-27.....	10 days	7.51	1.96	Feb. 25-March 16	20 days	7.08	1.70
	March 28-Apr. 18	22 days	8.06	1.47	April 19-May 5...	17 days	6.38	1.75
	May 6-17.....	11 days	9.07	1.08	May 18-June 2.....	15 days	7.17	1.43
	June 3-20.....	16 days	8.40	1.31				

What, we may ask, do these correlations mean? These fluctuations in pulse might, at first thought, seem to be due to the increased physical activity (finger and hand movements) involved in writing more lines of copy. This would make the pulse curves higher for all rises in the learning curves, as was the case, and would account for the close correlation between the efficiency and pulse curves. That this, however, was not the cause of the correlation is shown by the following facts: (1) The rise in pulse over the normal was as high and in some instances higher, for the early stages of practice where little was written, than for the later stages where five or six times as many strokes were made. Compare the figures on the curves showing the average rise in normal pulse for different stages of practice, Figs. II and XV. (2) In the practice sentence writing the pulse is higher in nearly every case where the least writing was done.

This latter fact is clearly shown in Fig. VII. representing the pulse and learning curves for the practice sentence writing of Z. As may readily be seen the pulse curve is higher for the plateaus in the learning curve (21st. 30th and 32d. 45th day) than for the period of rapid rise near the end of the practice (46th to 57th day).[1]

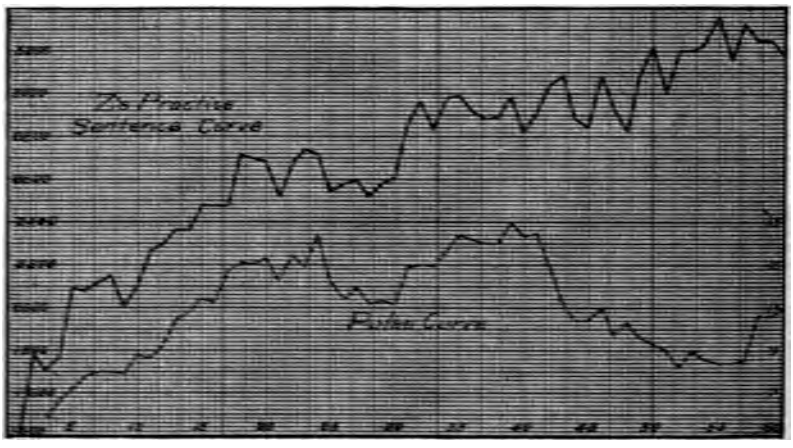


FIG. VII.

Fig. VII represents the practice sentence writing of Z (S. M.). The upper curve is his learning curve and the lower curve his pulse curve. The average rise in pulse above the normal is shown on the vertical axis to the right. The amount written, in strokes, by the figures on the vertical axis to the left. The time or number of tests taken is shown on the horizontal axis for both curves.

Both the pulse and learning curves were smoothed by taking an average of the first three days' record in each case, then the average of the second, third and fourth days, then of the third, fourth and fifth to the end, and recording the averages.

[1] Compare also the figures and behaviour of the lower curve in Fig. VIII. a diagramatic representation.

The same thing is shown in another way by the practice sentence curve of Y (upper curve Fig. VIII, same as curve "E", Fig. II), only his practice was stopped while he was still on a plateau, making it impossible to tell whether his pulse rate would also have decreased, as in the case of Z, when improvement began.

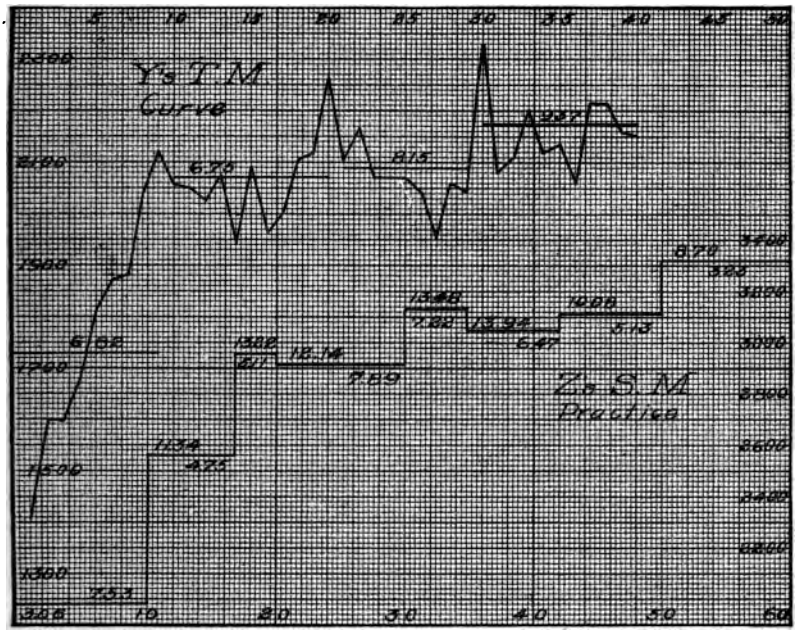


FIG. VIII.

Figure VIII shows Y's practice sentence curve (T. M.), the upper curve, and Z's practice sentence curve (S. M.) in diagramatic form, the lower curve. The number of practices, or days, is shown in each case on the horizontal axis (for the upper curve above, the lower curve below). The amount of work done in strokes on the vertical axis, for the upper curve to the left, the lower curve to the right.

The horizontal bars in the lower curve represent the average amount of work done during the period of practice indicated by their length. The figures set above these horizontal bars indicate the average rise in normal pulse for the period; the figures below the bars the per cent of errors for the period of practice marked by the length of the sections.

The figures on the horizontal lines drawn through the upper practice curve (Y's T. M. curve) show the average rise in normal pulse for the period represented by the length of the straight lines as measured by the horizontal scale. The height on the vertical axis at which these lines are drawn shows the average number of strokes made for the period of practice indicated by the length of the lines.

It was also determined that there was almost no correlation between the *efficiency* and pulse curves for the practice sentence writing. For the first minutes of the tests the efficiency curves were low, the pulse curves high. For the last minutes of the tests the efficiency curves show a rapid rise, the pulse curves a rapid falling off (Fig. IX).

We, therefore, conclude that the rise and fall of the pulse curves was not caused by the physical activities involved in the writing; for here the pulse is lowest in every case where the most writing was done and *vice versa.*

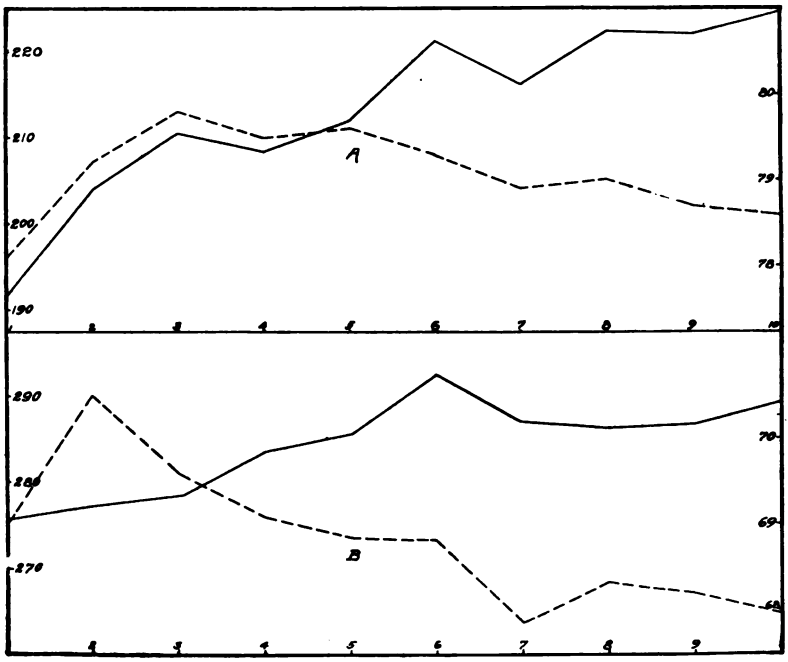


FIG. IX.

Fig. IX shows the pulse and efficiency curves for the practice sentence writing of Y and Z. "A" shows the curves representing the total T. M. practices of Y (40 days). The heavy line his efficinecy, the dotted line his pulse curve. "B" represents the total practice sentence writing (S. M.) of Z (60 days). The heavy line shows his efficiency, the dotted line his pulse curve.

The successive minutes of the tests are shown along the horizontal axis, 1-10. The average pulse rate is shown on the vertical axis to the right. The amount of work done, in strokes, on the vertical axis to the left. Both curves are drawn on the same scale.

What then do our pulse curves mean? Why is there a high positive correlation between the pulse, efficiency and learning curves for all the regular writing tests and an inverse instead of a direct correlation in all the practice sentence curves? As might be expected, many things influence pulse rate, as is shown by the lack of correlation from minute to minute and from day to day for the individual tests. But these accidental factors average out in a large number of cases, and allow more constant influences to appear. Such an influence and one that we should naturally expect to affect not only the learner's score but his pulse rate as well, is the amount of energy or effort, voluntary or spontaneous, put into the work. Strong effort and wrapped attention would increase both his pulse rate and writing score, lack of effort and dispersed attention cause a drop in both. This would account for the general correlation between the pulse and learning curves shown by all the regular writing tests and for the fact that in the regular practice the efficiency and pulse curves always rose and fell together. But what about the inverse correlation shown by our practice sentence curves? Does a rise in pulse rate always mean that more attention and effort have been put into the work? Do the differences in the character of the fluctuations in the pulse rate, which occur at different stages of the practice, mean variations in the amount of effort and attention put into the work?

Our facts warrant an affirmative answer. The observations of the learners showed not only that many variations in attention and effort occurred throughout the course of the practice but that they occurred at almost the identical stages indicated by the variations in our pulse curves. The learner's and experimenter's notes further showed why a rise in the pulse curves was not always associated with improvement or increase in writing score. Such a correlation could only be perfect, if the other factors influencing the pulse remained reasonably constant, and *if the energy expended was always efficiently directed.* The observations of the learners showed that the effort put into the regular practice was generally efficient. We should, therefore, expect a correlation between the pulse, efficiency and learning curves for the regular practice as was the case. The observation notes for the practice sentence tests, on the contrary, showed that here the learner's energy was almost never economically applied. His attention was carelessly

directed, not kept on the details of the work. As one of the learners expressed it: "Attention is on making the movements go fast, rather than on making certain well directed movements as fast as possible." As a result many conflicting associations were formed and the correlation between the pulse, efficiency and learning curves destroyed.

It was further determined from the notes that the subjects began their practice sentence tests with unusual or excessive effort; that they started out excitedly; tried to go faster than they could actually write. Our objective records show what, on our assumption, we should expect to find, namely, a high average rise in the pulse for the early part of these tests and a low writing score (see Fig. IX, above). Towards the end of a test when the subjects did not work so wildly and attended more carefully to the details of the work, the order is reversed; the work curve is now high, the pulse curve low. The efficiency and learning curves show the same fact (that in the practice sentence writing more energy was put into the work, but that it was wrongly applied) in still another way. From the notes of the experimenter and learners, and the errors made it was found that, for the first ten days of Y's practice, his effort was carefully directed. His learning curve shows a rapid rise while his pulse showed only the normal rise of 6.82 beats for the period. There is also for this period a high degree of correlation between his pulse and efficiency curves (A, Fig. X). But at this point in his practice Y reached a "critical stage" (compare upper curve, Fig. VIII, p. 113, above). His progress is arrested. His learning curve shows the beginning of a plateau. His notes clearly show that for this period of practice he got extremely nervous and put more energy into the work than at any previous stage, but that it was wrongly directed—directed to speed instead of to the details of the work. His average rise in pulse is, for this period of practice, 8.15-9.37, and there is no correlation between his pulse and efficiency curves, Fig. X, curve B. The former is high where the latter is low and *vice versa*.

That the subjects were trying unusually hard where their pulse curves were highest is further shown by the fact that Z, who seemed to try harder in his practice sentence writing than any of the learners, injured the Ulner nerve in his fore arm so severely while on his practice sentence plateau, that he was

forbidden by his physician to write with a pen for months, and did not fully recover from the effects of the strain for almost a year. But little improvement was made during these periods of strenuous practice because attention was wrongly directed. The learners worked like balky horses. As soon as they learned to put forth only so much energy as could be economically applied to the work at that stage and learned to keep attention again on the proper details of the work, their learning curves started rapidly upward and their pulse settled down once more to a normal rise.

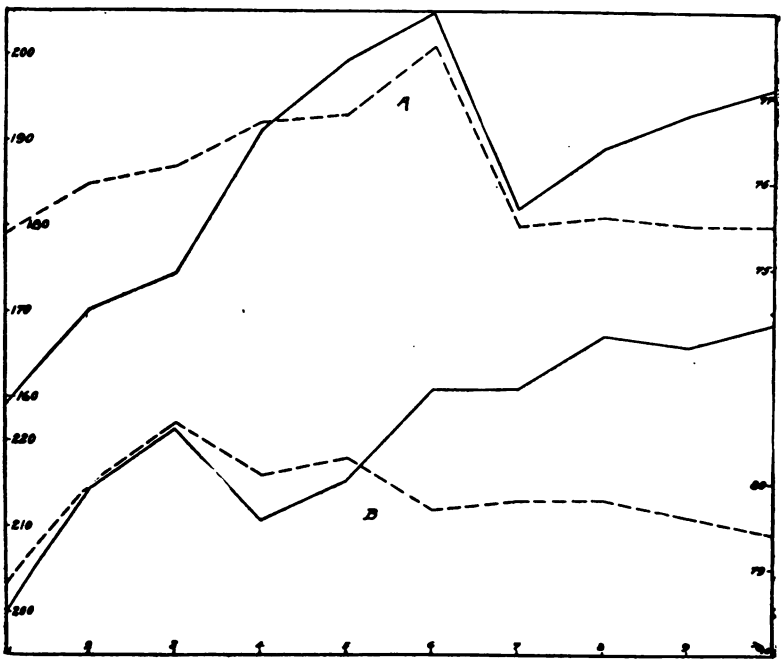


FIG. X.

This figures represents Y's work and efficiency curves for different stages of his practice sentence writing. "A" for a period of rapid progress, the first ten days of his practice, "B" for the next thirty days of his practice, where no improvement was made.

The heavy line in each section shows the average amount of work done (in strokes) in each minute of all the tests of the period. The dotted line represents the average pulse rate for the different minutes of the period.

The curves are drawn on the same scale. The figures on the horizontal axis show the successive minutes of the tests. The figures on the vertical axis to the right, the average rate of pulse, the figures on the vertical axis to the left, the average number of strokes made on the machine.

We, therefore, conclude that a rise in pulse rate means that more attention and effort were put into the work, a drop in our pulse curves a lapse in attention and effort. The general correlation is so close, and the exception in the practice sentence so easily explained, that we may take the larger variations in our pulse curves as confirmatory evidence of the variations in attention and effort observed by the learners and use them with confidence in our explanation of the learning curves.

(b) Mistakes.—Additional evidence for the fluctuations in attention and effort presently to be described is to be found in the mistakes which the learners made. They were told, when the practice began, to write always at a maximum rate, but to avoid all mistakes. (If in the course of the writing a mistake should occur, they were directed to go on writing without stopping to correct it). Notwithstanding this charge many mistakes were made, and their frequency varied almost directly with the fluctuations in attention and effort which occurred. In fact so close is the correlation between the kind and number of mistakes made and the fluctuations in attention and effort, that the mistakes, instead of the observations of the learners and pulse curves, might have been used to determine the fluctuations in attention and effort. They were a reliable index of how the learner's attention worked on any particular day or at any stage of the practice. During the bad periods and on the bad days the tendency to make mistakes was much greater than at other times. The learner's attention worked less spontaneously and his effort was more apt to become slack or to be misapplied. As a result more mistakes were made. There were days when the written records for the day showed twice as many mistakes and a lower writing score than for the previous or following day.

The *daily* fluctuations in the percentage of errors are, however, less important than the larger changes which occurred at different stages of practice. For the periods of rapid improvement there is a gradual decline in the percentage of errors, under the influence of the general habit of dealing more carefully with each individual difficulty as it arose (see pp. 69-71, above). But as stages were approached, where the learner put less energy into the work and directed his attention less carefully, the percentage of errors greatly increased. For all the learners most errors were made at those stages of practice where the pulse curves gave evidence of a marked failure in attention

and effort or where the notes of the learners showed that excessive effort had been ineffectively applied (compare percentages of errors and learning curves, Fig. XV, p. 140). Moreover a different sort of errors was made, depending upon the kind of variation in attention and effort going on.

With the relaxation of attention characteristic of certain stages of advancement (the "critical stages"), there always went a marked increase in the following kinds of errors. The learner got more careless about locating the keys: (1) More often struck in between them; or (2) struck the key next to the one to be struck; or (3) struck the space bar before he had finished the word; or (4) reversed the order of the letters in certain words; or (5) struck a letter in a corresponding position but on the wrong half of the keyboard, e. g., *e* for *i* (T. M.); or (6) changed slightly the wording of the copy by using synonyms, etc. (S. M.); or (7) omitted a word or phrase of the sentence copied at the time (S. M.); or (8) repeated a word or phrase (S. M.); or (9) got the little fingers misplaced and wrote as before, but on the wrong row of keys (T. M.), etc.—all because his spontaneous attention had been turned away from the work, and had left to automatic centers tasks for which they were as yet unprepared. When too great effort was put into the work and attention was pushed ahead too fast (a not uncommon after-effect of the relaxation in spontaneous and voluntary attention just mentioned), the learners made mistakes like the following: (1) Letters were omitted or struck too lightly to record; (2) two letters were struck simultaneously; (3) the space bar was struck before the finger was raised sufficiently from the last key; (4) the stroke on the space bar was omitted or made too lightly to cause the carriage to move; (5) letters were doubled or repeated; (6) the stroke was made ahead of time, etc.,—all because attention was kept on speed, instead of on the steps that had to be gone through with and consciously guided in order to write well at that stage of advancement. The mental spelling was neglected.[1]

[1] The particular causes of these mistakes and the psychological processes involved in making them are of general psychological interest and were minutely described by the learners, but we are in this study concerned only with their cause and effect so far as related to learning and rate of work. The mistakes made in typewriting are in most respects analogous to the mistakes made in pen writing and slips in speech, the psychology of which has in part been worked out. The mistakes made in typewriting showed little that was new in this regard.

In every case the mistakes were a direct result of some of the variations in attention and effort which occurred and therefore showed the kind and degree of fluctuations going on. They are related to learning in two principal ways: (1) They further aggravated the fluctuations in attention or effort then going on, either by calling attention to themselves and so taking attention off the work, or by filling the mind with unpleasant feelings on their account, often by both. (2) Certain mental tendencies and associations were regularly formed by the practice in error, which in the future interferred with the action of the associations involved in correct writing.

Having briefly considered our objective evidence for these fluctuations in attention and effort we may turn to the variations themselves.

(c) Fluctuations in Attention and Effort Within a Test.— The first variation in interest (spontaneous attention) and effort (voluntary attention) to be described is that which occurred throughout the course of a single test. Two kinds of variations occurred. (1) An *irregular* fluctuation in spontaneous attention, on the one hand, and in voluntary attention or effort on the other. (2) A *regular* variation in voluntary attention or effort.

(1) The Irregular Fluctuations.—There were periods in every test lasting from a half to two or three minutes, when the learner's natural spontaneous attention had to be strongly supplemented and in some cases entirely replaced by the less efficient and more fatiguing voluntary attention, other periods when spontaneous attention needed little or no support from voluntary attention. At the close of his test on June 5, Y wrote:

"The writing of the whole period today was characterized by short, lucid periods in which every association came up spontaneously and easily, accompanied with good orientation on the keyboard, alternating with relapses when I felt entirely lost on the keyboard and when nothing went easily and well." On June 3, X wrote in his notes: "Had several bright periods today when everything went well. Other periods when it seemed to take much more effort to write. In the latter periods I simply could not direct my attention to the needed things. I seemed to have to work harder to make any process go. Everything seemed to be clogged up and I had to resort to earlier methods of writing, attending more to each detail of the work. In the good periods all the associations worked easily and well.

Only about half as much attention seemed to be needed and this flowed to the right details, it seemed, more of itself. My fingers which gave me trouble in the bad periods, by getting tangled up, in the good periods, limbered up and moved so easily that it was a pleasure to feel their movements."

It was determined that this failure in *spontaneous* attention or interest was apt to be followed or accompanied by a lapse in voluntary attention or effort and presently, when the decreased efficiency was noticed by the learner, by an almost uncontrollable desire to overcrowd himself to try to make up for the low score which the lapses in attention and effort were producing. The daily notes of the learners were full of such sentences as these: "I suddenly realized several times today that I was not doing my best. I am sure the writing went faster and better after that." "There are periods in almost every test where I do not and seemingly can not apply myself so strenuously to the work as at other times." "Could write easily today but could not keep up a maximum degree of effort throughout the test," etc. That the learners' observations on this point were correct is shown in a striking way by the behavior of the working pulse. On several occasions in the practice sentence writing, the pulse showed a variation for different minutes of the same test as great as eleven or thirteen beats. In the regular writing the variation was somewhat less but there were many days which showd a variation as great as eight or nine beats for different minutes of the same test and this when the learners were doing their best to work at a uniform maximum rate. Our tables further showed that for the different minutes of certain tests there was great irregularity in the working pulse (compare table IV), on other days a marked regularity.[1] This was shown

[1] It must not, however, be inferred that steady pulse always meant a high score or rapid improvement. For our learners it generally meant just the reverse. There was for all our leaners less irregularity in the daily working pulse (i.e., the M. V. was smaller) for the periods of practice where the longer lapses in attention and effort occurred (the plateaus) than for the periods of practice showing rapid improvement. Neither must it be inferred that an irregular working pulse always means high scores and improvement. It might mean this or it might mean that great effort was being wrongly applied to the work. Another important fact in this connection is, that while the pulse gets steady for the periods of practice where the larger lapses in attention and effort occur, the variations from day to day at these stages greatly increase, suggesting greater irregularity and unsteadiness in the effort put into the work from day to day, but an increased steadiness during the tests. Our evidence for this statement is that the mean variation of the mean variations for the successive days was higher for the "critical stages" in every case.

in a striking way by calculating the mean variations for the pulse rates of the several minutes of all the tests. These mean variations for the several days of practice not only indicated the amount of unsteadiness in attention and effort for the several days, but enabled us to determine the degree of fluctuation which occurred at different stages of practice.

The cause of these irregular fluctuations in attention and effort may be inferred from the following facts:

(1) They were wholly beyond the learner's control. He could not avoid them and could do little to regulate or control them.

(2) They were always followed or accompanied by unpleasant feelings which tended further to decrease the amount and efficiency of the effort put into the work by restricting the incentives to the sort of activity then going on.

(3) Sense discrimination was noticeably dulled; every association and mental process involved in the writing worked less freely than formerly; more distractions came in because attention could not be held on the details of the work.

(4) The fluctuations were noticeably numerous and troublesome on certain days and lacking on others.

These facts all point to fatigue as the dominant factor in causing the fluctuations in question. A uniform rate of writing can not, of course, be kept up throughout a test, for this would mean that the writer's spontaneous and voluntary attention was uniformly sustained, which is physiologically impossible.

The number, length and succession of these irregular fluctuations would, therefore, seem to depend upon the hygienic condition of the nervous system and of the body in general at the time of the test as well as on the difficulty of the work.[1]

The effect of these irregular variations in attention and effort on learning and rate of work is evident. The fluctuations are responsible for the erratic variations in the learner's writing score. A comparison of the number of strokes made from minute to minute in all the tests showed a variation extending all

[1] Some of the fluctuations in the learner's efficiency had, in all probability, quite a different cause,—were in fact nothing more than chance combinations of associations or mental processes favorable to the writing, a happy neural combination advancing typewriting skill. This is not only in harmony with the fact that introspection could find no cause for the fluctuations, but also with the manner of their appearance and disappearance. Such an interpretation is also favored by the fact that all adaptations in the learning were made in the same sort of lucky chance way.

the way from a difference of a few strokes per minute to minutes, which showed a gain of almost a third in total amount.[1] And, like the variations in attention and effort an even score was often kept up for almost the entire test on certain days while on other days there was great irregularity in the minute scores (compare sample records, table IV). The degree of unsteadiness which occurred was shown in a striking way by the mean variations for the minute records of the several tests. These not only showed the degree of variation which occurred during the course of each individual test, but enable us to compare the irregularity for one day with the preceding and following day, and also to determine the degree of irregularity which occurred at different stages of practice. This was done, but the matter is too complex for a general statement.

Of the relation of these smaller variations in attention and effort to learning we shall have more to say anon. The particular variations which occurred during the course of any test not only influenced the learner's score for the day but tended regularly to accumulate, in accordance with the operation of the law of habit, to form the larger fluctuations in attention and effort characteristic of the practice for the several days. The learner's attitude or interest for a particular day was largely determined by these irregular fluctuations in attention and effort, while the interest or *ennui* thus aroused influenced his attitude towards the work for succeeding days.

(2) Regular Fluctuations Within a Test.—It has long been known[2] that the amount of work which an individual would accomplish, if called upon to do continuous mental or physical work, varied in characteristic ways depending upon the individual workers and the length of the period of work. The typical work curve shows a marked increase in efficiency for the first and last minutes of such periods of work, due, it is believed, to an initial and final spurt in effort, the Anfangs—und Schlussantrieb of Rivers and Kraepelin. Our pulse and

[1] This fluctuation in efficiency is not caused by objective difficulties, irregularities in the copy, etc., as at first thought might be supposed. The objective conditions were kept constant and greater fluctuations occurred in the practice sentence writing where the copy was uniform than anywhere else, and in the letter association stage of the regular T. M. writing, where the copy gave the writer no difficulty whatever (see p. 29), the variations in efficiency were as great as in any of the regular writing.

[2] Compare Ebbinghause, "Uber das Gedachtniss," Leipzig, 1885, pp. 57-8. Kraepelin's "Die Arbeits Curve," **Philosophische Studien,** Vol. XIX, 1902, pp. 449-507, Kraepelin's **Psychologische Arbeiten,** Vol. I, p.

TABLE IV.

Min.	1		2		3		4		5		6		7		8		9		10		Ave. Strokes Per Minute	M. V.	Ave. Working Pulse	M. V.	Normal Pulse	Ave. Rise in Normal Pulse	Percentage of Errors	Total Strokes
Date	Strokes	Pulse	Strokes	Pulse	Strokes	Pulse	Strokes	Pulse	Strokes	Pulse	Strokes	Pulse	Strokes	Pulse	Strokes	Pulse	Strokes	Pulse	Strokes	Pulse								
Mar. 21	75	69.5	64	69	69.5	69	68.5	71	69	71.5	70	69	67	71	71.5	71	73	73.5	72.5	71.5	69.9	2.40	70.6	1.18	66	4.6	2.58	699
Apr. 14	109.5	67	104	67	113	67	131	69	90	66	105	64	116.5	65	132	66	111.5	65	107	69	111.95	8.94	66.5	1.30	61	5.5	1.07	1119.5
Apr. 15	104	61.5	109.5	64	119.5	63	123	63	100	63	122	64	129.5	65	116	64	92.5	62	128	61	114.4	10.32	63.05	.96	57	6.5	1.66	1144
Apr. 16	115	55.5	93.5	55.5	98	57	125.5	58	86	56	92.5	56.5	116.5	59.5	110	62	94	61	107	61	103.8	11	58.7	2.14	52	6.2	1.54	1038
Apr. 20	116.5	63.5	95	62	103.5	65.5	126	66.5	120.5	66.5	87	62.5	101	63	117.5	63.5	101.5	63.5	142.5	65.5	111.1	13.50	64.2	1.44	57	7.2	2.25	1111
Apr. 21	141	64	117	64.5	106.5	66	134.5	67	99.5	67	116.5	67	107	67	129	69	114	67	118.5	67.5	118.35	9.98	66.6	1.06	62	4.6	1.52	1183.5
Apr. 22	122.5	64.5	126.5	64	118.5	64.5	129	64	127	64.5	121.5	63	123	65	131	66	125.5	61	137	68	126.15	3.95	64.45	1.16	54	10.45	1.11	1261.5
Apr. 25	127	60	118	60	126.5	59.5	107.5	58	112	61	108.5	59.5	101	58.5	116.5	59.5	117	58.5	104	61	113.9	7.10	59.55	.76	54	5.55	1.93	1139
Apr. 26	134	62	99.5	65	104	63	132.5	66	124.5	65	130	64.5	130.5	63.5	122.5	65	120.5	65	138.5	64	123.65	9.62	64.3	.94	54	10.3	1.45	1236.5
June 6	121	62.5	138	64.5	136.5	65	141.5	67	157.5	67	152	68	130	68.5	154	70.5	168.5	68	125.5	66.5	143.85	12.12	66.75	1.70	62	4.75	1.11	1438.5
June 7	156	60	144.5	62	142.5	67	141	63.5	147.5	63	150	63	152	64.5	147.5	63	151	61	165	65	149.7	5.10	62.7	1.16	55	7.7	1.53	1497
June 12	145.5	66.5	186	71	187.5	68	225.5	73	235.5	73	223.5	71.5	172.5	68.5	195.5	73	200.5	70	187.5	68	195.95	20.24	70.25	2.05	65	5.25	.45	1959.5
June 13	185.5	77.5	182	79.5	183.5	80.5	226.5	80	169	80	212.5	80	167.5	78	211	78	181.5	80	245.5	79	196.45	23.94	79.25	.90	71	8.25	.44	1964.5
June 21	158	71	210	77.5	222.5	78.5	174	74	229	79	225	72.5	174	75.5	220	73	195	74	220.5	75	203.3	21.94	75	2.10	68	7.	.45	2033
June 24	208	81	189	81.5	217.5	83.5	203	83	198	83	185.5	81	230	82	210	83	186.5	83	227.5	82	206	13	82.3	.80	76	6.3	.47	2060
July 15	245	82	233.5	74.5	241.5	82.5	221.5	84.5	254	82	257.5	76	233	76	223.5	77.5	274.5	79	233	74	241.05	12.20	78.8	3.20	67	11.8	.50	2410.5
July 18	185.5	76	185	76	203	78	221.5	77	222	78	230.5	78	229	75.5	238	77.5	229	79	231	77	217.45	15.77	77.2	.90	65	12.2	.43	2174.5
July 19	210.5	89	217.5	90	236.5	89	230	90	228	89	210	86	195	89	237.5	89	223	86	212.5	89	220.05	9.95	88.6	1.00	80	8.6	.43	2200.5

Eight records from regular S. M. writing of Z (first eleven lines), and five daily records from Y's writing of a practice sentence (T. M.), last seven lines, given to illustrate kind of data contained in complete tables and the irregular variations in pulse and score which occurred from minute to minute throughout the tests.

efficiency curves enable us not only to verify the results and conclusions of previous investigators on this point, but reveal an additional fact which the writer believes to be important and new. It has been generally assumed that the work curve, though different for individual learners, remains the same for any given individual for all stages of learning, and all kinds of work. (Compare Kraepelin's Arbeits Curve, *Philosophische Studien,* Vol. XIX, pp. 459-507). Our results clearly show that this is not the case. Our learners had characteristic modes of procedure as the older studies have shown, but they did not go about the work in the same way at all stages of practice. In other words the work curves for our learners were not alike for different stages of their practice. For the periods of practice which showed regular and rapid improvement they revealed the usual characteristics. For the periods of practice represented by the plateaus in our learning curves the initial and final rise in the work curve was lacking and there was less evidence of the warming up. This will be made clearer by a comparative study of our curves.

Fig. XI represents the pulse and efficiency curves for the regular S. M. writing of X and Z; the upper curves those for the total practice period of Z, 86 days; the lower curves for the practice of X, 174 days. They are drawn on the same scale and in each figure the heavy lines are the efficiency, the dotted, the pulse curves. The successive minutes of the tests are shown along the horizontal axis from 1 to 10. The average pulse rate is indicated on the vertical axis to the right. The amount of work done in strokes on the vertical axis to the left.

A mere glance at our work curves (heavy line, Fig. XI) will show that there is a marked high start (higher than the rate for the second minute) and a final rise in efficiency for the last minute of the tests. The curves for the T. M. writing do not show the initial rise in efficiency (compare heavy line, Fig. VI, and upper curves, Fig. XII, pp. 105, 128). There is a gradual rise up to the fifth minute of the tests followed by a decided drop the next two minutes and a final rise the last three minutes of the tests. The increase in efficiency for the first five minutes of the tests would seem to be due to the relearning

636 f, and Vol. III, pp. 509-514, studies by Rivers and Kraepelin and Lindley, also Muller and Schumann, Experimentelle Beitrage zur Untersuchung des Gedachtnisses, **Zeitschrift f. Psychologie und Physiologie der Sennesorgane,** Vol. VI, 1893, p. 320 f.

and warming up already described (pp. 102-108). There was no drop in effort after the first minute of these shorter T. M. tests because there was no thought of a long period of practice ahead to reduce the enthusiasm with which the learners started their tests. They started in at their best rate which they kept up until overcome by fatigue towards the middle of their tests. This caused a relaxation of attention and effort, but as they neared the end of their tests, which they could judge pretty

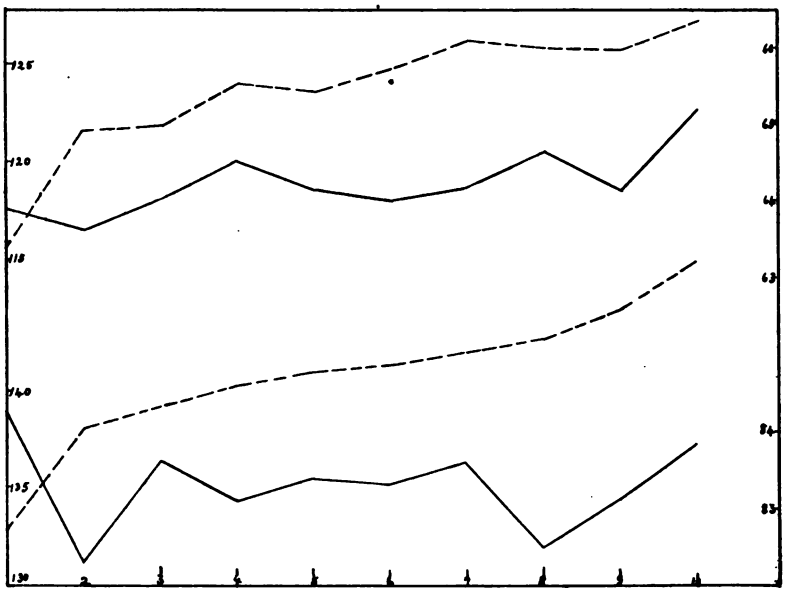


FIG. XI.

accurately, they again urged themselves on to greater endeavor, the final spurt in effort accounting for the increased efficiency for the last one or two minutes of the tests.

In the S. M. learning on the other hand (Fig. XI), where the tests were thirty minutes long, the high degree of effort with which the learners started their tests could not be kept up. Their spurt of enthusiasm was conquered by the unconscious thought of the long period of work ahead. Not to take it more easily would have meant to break down before the end of the test. We may, therefore, conclude that the drop in their curves for the second minute was caused by a relaxation of attention or effort while the slight rise after this was due to relearn-

ing and warming up, extra effort being again put into the writing as the end of the first third of the test was approached, where time was called. For a short period preceding this signal, less power was held in reserve and more energy thrown into the work.

That the initial and final rise in our curves was due to such a regular increase in voluntary attention or effort,[1] we conclude from the data given by our pulse curves and the learners' and experimenter's notes. The spur to effort was called forth in a purely unconscious and reflex way by the natural conditions of the experiment, still the learners often said in their notes for the bad days that even the calling of time did not seem to arouse them to better work, while the effects of both the initial and final spur to effort were observed by the experimenter and dscribed in his notes, as well as suggested by the final rise in the pulse curves. In every case the pulse curves show a corresponding rise the last minute of the tests. That the pulse curves do not show the effect of the initial spur to effort is probably due to the fact that it takes a little time for the pulse to get up a normal working momentum. In that case the slight decrease in effort the second minute of the tests would be more than counteracted.

But this verification of certain results and conclusions of other investigators is of minor importance when compared with the fact that the form of our work curves varied for different stages of practice. Figures XII, XIII, XIV represent the work and pulse curves of our learners for different stages of practice. The upper curves in each figure mark a period of practice showing rapid improvement. The lower curves represent plateaus in the learning curves or period of practice where no improvement was made. Figure XII represents the T. M. practice of Y. The upper curves show the amount of work done and the average pulse rate for each minute of the tests from the beginning of his practice to the time where his plateau set in, a period of 97 days. The lower curves give his pulse and work curves for the period of his plateau, 32 days (compare

[1] The rise in efficiency the last minute of the tests has been attributed by Muller and Schumann (Experimentelle Beitrage zur Untersuchung des Gedachtnesses, **Zeitschrift fur Psychologie und Physiologie der Sennesorgane,** Vol. VI, 1893-94, p. 322 f) to the relief which comes with the approach of the end of the test. But this will not account for the final rise in our curves because there was in reality no relief ahead of the learners, their tests were only a third finished.

his learning curve, Fig. II, p. 20). Fig. XIII represents the S. M. practice of Z. The upper curves represent the period of most rapid rise in his learning curve, the first 70 days of his practice (see learning curve, Fig. II). The lower curves represent the period of non-improvement towards the end of his practice. Fig. XIV represents the S. M. practice of X. The upper curves the period of most rapid improvement preceding his second plateau, 47 days (see learning curve, Fig. II). The lower curves the period of practice for his second plateau, 32 days. The curves are all drawn on the same scale. The heavy lines are the work or efficiency curves, the dotted lines the pulse curves. The successive minutes of the tests are shown on the horizontal axis. The average amount of work done, in strokes, is shown on the vertical axis to the left. The average rate in pulse is shown along the vertical axis to the right.

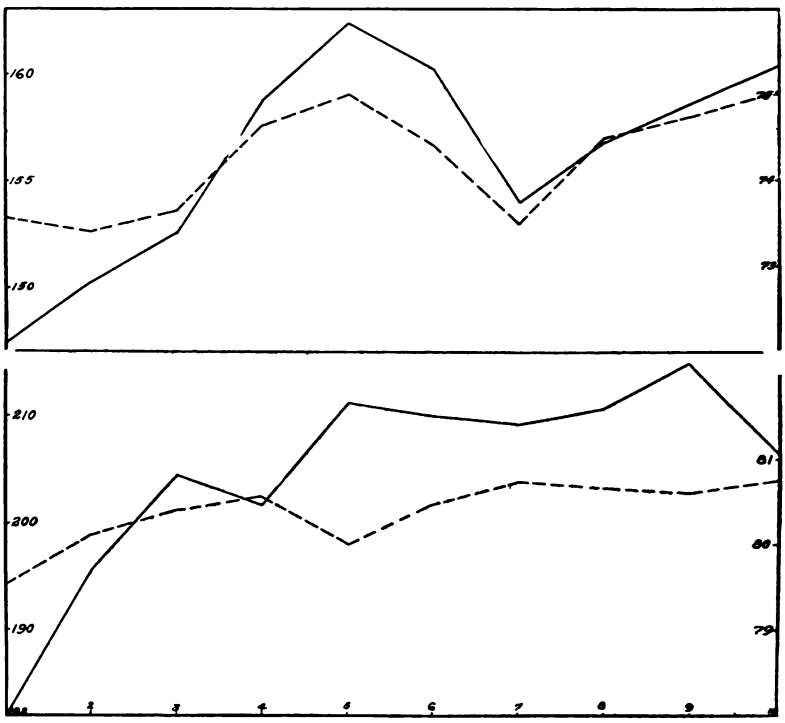


FIG. XII.

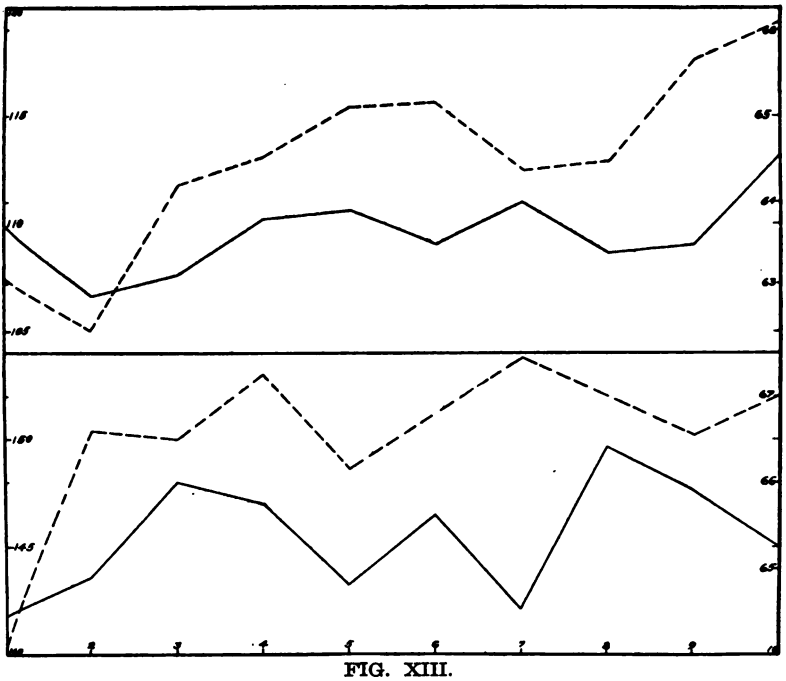


FIG. XIII.

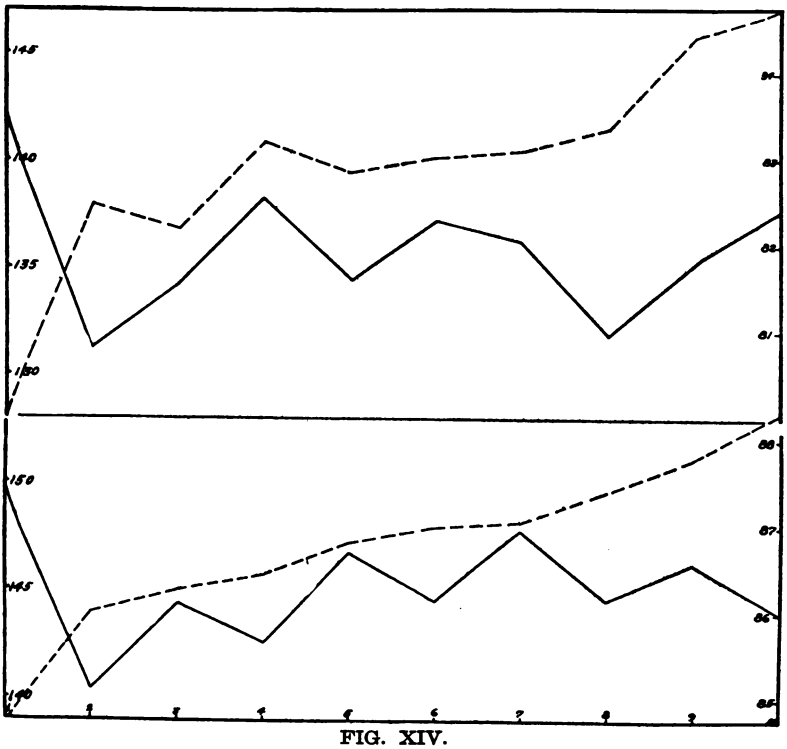


FIG. XIV.

These curves clearly show that with the change in attitude and slackened effort characteristic of the periods of practice where no improvement was made (the plateaus in the learning curves), there regularly went, in the case of our learners, certain characteristic changes in their manner of approaching the work. Without exception the initial and final intensification of effort in the first and last minutes of the test, so characteristic of all periods of improvement, is lacking or noticeably diminished for the periods of practice corresponding to a plateau in the learning curves, but another way of saying, it would seem, that less effort was put into the work at these stages (see p. 140) The curves also show less evidence of warming up for the plateau practices.

The significance, for learning, of this variation in voluntary attention or effort will be seen when it is remembered that new adaptations or forward steps in learning were only made when intense effort was rightly applied to the work. At the "critical stages" where a natural and marked decrease in spontaneous attention and effort occurred no improvement was made. The learner was caught by the law of habit and was content to use old methods of writing when he should have been forging ahead inventing new and better ones. The important fact is not that an initial and final spur to effort should generally occur but that it was lacking at the *"critical stages"* where the lapse in spontaneous attention and effort occurred. It seems but another way of saying that at the stages of practice where little or no improvement was made less attention and effort was put into the work.

(d) Daily Fluctuations in Attention and Effort.—Variations in attention and effort of still more importance for learning than those just described are the fluctuations which occur from day to day.[1] In our typewriting experiments there were many days when the learner's *spontaneous* attention seemed to work perfectly throughout almost the whole test, and days when

[1] These daily fluctuations in attention and effort should not be confused with the diurnal changes in efficiency found by Lombard, Kraepelin and Marsh (see especially **Archives of Phil., Psy. and Scientific Method,** Columbia Contributions to Philosophy and Psychology, July, 1906, pp. 42-92). Our tests were made at the same time of day, hence the variations which occur are such as occur from day to day when doing the same sort of work under the same objective conditions. And it should not be forgotten that these variations were found not in the work of children or casual subjects, but in that of conscientious adults, used to systematic work.

everything about the writing had to be forced. Typical descriptions of the good days are the following:

"Everything went easy today. Struck more letters without seeing them than ever before. All movements were easy and my co-ordinations good. All energy seemed to flow of itself into the needed movements. I was ready for every word as I came to it and could easily react to words and phrases as a whole. It was like play, it seemed so easy and pleasant," (X, April 7). "Felt throughout the test that I was doing well. I broke away from the old plan of holding myself back for I could go fast and still get it right. I wrote every word as fast as my fingers could move. The places where I had trouble before I ran over today without difficulty," (Z, April 2). "The movements today were unusually easy. It was not only easy to get the right letter, the movements themselves seemed to be of the right intensity. Just the right amount of energy could be turned loose, it seemed. Every part of the work seemed to come of itself, which made me feel real good," (Z, April 4). "Did not have to make myself try once. Could, by the spontaneous effort that came of itself, write at a more rapid and uniform rate. I felt especially good. Thought several times of my research and was pleased because I was getting along so well," (Z, May 6).

The bad days were described in such phrases as these:

"Could not keep clearly in mind today what was next to be done," (X, April 6). "Had all sorts of trouble. Could not keep my mind on the work. This fact, when I noticed it, took charge of the focus of consciousness and I could not get my attention back on the work. I tried to hurry, but this only made matters worse. Got so impatient that several times I lost my way on the keyboard. Towards the end of the period was bothered by the thought that time was almost up. I think that I never tried harder than I did today, but this only made matters worse. My attention was off and could not be whipped into line by any manner of means. I was tired to begin with and felt out of sorts," (Z, June 8). Y generally described these off days by saying that he "did not seem to be able to keep the necessary things in mind as well."

Great variations also occurred in the amount of *voluntary* energy or effort put into the work on different days. In the learners' notes we find such expressions as these: "Seemed to put more energy into all parts of the work today," (Z, May 13). "Wrote only with an average enthusiasm today; seemed to have half in mind all the time that I was going to get started better soon, make a spurt, but time was called before this happened," (Y, June 15). "Noticed several times today that I was not pushing myself as much as I could," (X, June 7), etc. In the experimenter's notes we find such phrases as these: "Seems very much alive today. Shows every sign of being in a hurry; opens his eyes wider when reading the copy; turns more rapidly to the keyboard after a section of copy has been learned, and in many other ways shows signs of effort not noticed for several days." On the lazy days we find such expressions as these: "Seems less alert than yesterday; no evidence of effort; was more alert for a minute, but it did not last; did not seem to care when a tangle on the keyboard came; is inclined to settle down

to a slow and regular rate of writing; has every appearance of applying himself less vigorously to the work," etc.

This daily fluctuation in voluntary effort is shown in yet another way. The average daily rise in normal pulse varied for X, from 1.95 beats on the day showing the least average rise, to 15.9 on the day showing the greatest average rise.[1] For Y the range was from 1.3 to 12.8 for his regular writing and from 3.2 to 14.6 for his practice sentence tests. The variation for Z was from 1.55 to 12.0 for his regular tests, and 4.5 to 16.35 for his practice sentence tests. These variations in working pulse, though as great as that of the daily scores, can not, of course, be taken as an exact measure of the fluctuations in effort from day to day, for many other things besides the amount of energy expended influences the pulse; but taken with the observations of the learners and the signs of such a variation in effort recorded by the experimenter, the variations in working pulse confirm the learners' and experimenter's reports that such daily fluctuations in voluntary effort occurred.

A third fact revealed by our data was, that when the fluctuations in attention and effort above described were noticed by the learner, they were almost invariably followed by lapses in the efficiency of the effort put forth. The kinds and number of mistakes which the learners made proved to be an unmistakable index of their voluntary efficiency. As soon as there was a lapse in spontaneous or voluntary attention there was a marked increase in the first group of errors described on page 119. As soon as there was a lapse in the efficiency of the effort actually put forth (i.e., trying harder but more carelessly), there was a marked increase in the second group of mistakes we described. The kind and number of errors made on any day and for any period of practice, therefore, revealed the degree of efficiency of the effort put into the work and showed that such fluctuations in voluntary efficiency occurred.

To understand or explain these daily fluctuations in attention and effort we must take into account all the facts. It was determined:

1. That with a lapse in spontaneous attention there regularly went a dearth of incentives to efficient effort; that is to say, with a bad day there usually went failure in voluntary attention and effort as well as in spontaneous efficiency. The

[1] For method of getting the normal pulse see p. 11.

learner had to invent and rely on all sorts of devices to push himself along and by artificial means make up for incentives to work spontaneously present on the good days. Instead of aiding the learner the whole organism, on the bad days, seemed to be putting on the brakes; and finally, if the learner by a spurt in voluntary attention kept his effort at a maximum, it was apt to be wrongly applied, and so count neither for learning nor for increasing his score.

2. With these fluctuations in efficiency there always went certain changes in the learner's general affective tone, a change in attitude or mood, which in turn, reacted upon his power of turning off work.

3. There were often reported, on the bad days, notable changes in the learner's physical and hygienic conditions, changes which had a retarding effect on all the psycho-physical processes involved in the writing. We often find such expressions as these in the notes for corresponding days: "Did not feel so wide awake as yesterday at any time." "Was very tired and out of humor." "Was tired and not thoroughly alive to seeing the letters." Typical quotations for the good days are: "Had just taken a refreshing nap. I am coming to believe more and more that my general mental and physical condition is responsible for these daily fluctuations in efficiency." "Believe my physical condition was better today than for several days. Did not feel nervous or worried at any time."[1] etc.

4. Not alone the amount of work, but its character also was affected by these fluctuations, and in certain definite ways. On a good day the writing was done on the highest plane so far attained. The latest associations and the newest and most advantageous short cuts in method could be used. Special difficulties could be more easily solved and distractions promptly dismissed. All co-ordinations were easy and the movements of the right intensity. The span of attention was greatly increased, the motor-tactual "feel" distinct, and visual attention especially keen, the eyes and attention were always where they ought to be, etc. On a bad day when the fluctuations were

[1] But the subjects were found uncertain judges of their exact efficiency. They either were careless about the analysis of their condition or else the feelings are not to be depended upon as a measure of efficiency. Feeling that he could make a good score, or determining to break all previous records, by no means meant that the learner would do so. In fact there were a few marked cases where loss of sleep, headache, etc., seemed actually to stimulate the learners.

conspicuously present all this was reversed. Nothing went as it should—at least not for more than an instant at a time, and the learner had regularly to resort to more primitive ways of writing. Even in the later stages of practice the learners often complained, on the bad days, that letter associations were about all they could use.

5. The last and most important fact to be considered in explaining these lapses in efficiency is that they were so completely beyond the learner's control. Something seemed to have taken away all his spontaneous incentives for work and his power to direct his energies. He might put forth more energy, but if he did, it could not be directed to the needful things. As one of the subjects expressed it: "Putting and keeping the attention on the work is like going to sleep. When you try to do it, you can't. You must fall into it spontaneously." Or again, "there are periods and days when I cannot try, or apply myself to advantage, as well as I can at other times. Today could place no attention on the work. My energy vainly went into the trying. Soon the writing began to go better and a sort of spontaneous attention for the work developed. I could then put my whole energy into the work, and rightly attend to all the details. I only watched the succession of movements and made such movements or groups of movements as quickly as possible. At times this spontaneous attention relaxed and I did very poorly. By no manner of means could I then write so well. The good days seem wholly independent of how hard I try."

These facts and observations taken together point as before to one fundamental explanation, namely: The daily fluctuations in efficiency mean variations in the general mental and bodily condition of the learner and are indicative, especially, of his neural tone. With or against this the various physical influences operate. The analysis of these physiological and hygienic conditions would lead us too far afield, but general fatigue (due to other causes than the labor of the experiments), and the amount and character of the food and sleep taken, the condition of the weather, atmospheric pressure, temperature, etc., would of course be found operative.[1]

[1] It is interesting to note in this connection the variations in normal pulse for successive months. Though taken at the same time each day, and with the utmost precautions (see p. 11), the pulse was found to vary greatly as the season advanced. Table V, below shows the average normal pulse for the different learners by months.

But the neural condition of the learners is not entirely responsible for these daily fluctuations in attention and effort. The law of habit is operative here. Relaxed attention, or the effects of a lapse in effort and enthusiasm, or the effects of a "rattled" or nervous state of mind characteristic of a decrease in voluntary efficiency, as well as the mental states, which characterize successful work, tend naturally and regularly to accumulate from minute to minute and day to day, as do the sensations or feelings to which the work gives rise (see p. 152, below). It was found that the kind of interest or effort put into the work on any particular day vitally influenced the learner's interest or attitude towards the work on succeeding days. The particular weariness or general inertness conspicuously present at the beginning of practice on certain days and dominant during other tests was often the result of habit. A severe fit of laziness on any particular day steals away part of the enthusiasm for succeeding days. Nothing was found so good for progress on a particular day (provided, of course, the general hygienic condition of the learners had not materially changed) as success on previous days, while a bad day always choked the learner's enthusiasm and dulled his interest for succeeding days. One or two nervous or lazy days, brought on by any cause whatsoever, tended to bring on lapses in effort and attention, which might continue several days, developing into the longer irregular lapses in attention and interest present at the "breathing places" in the learning curves. The effects of these longer lapses, in

TABLE V.

Subject.		March.	April.	May.	June.	July.	Time of Test.
X	Average Normal Pulse	75.60	77.50	77.86	77.78		
	M. V.	3.36	3.13	4.05	3.57		4:00 p. m.
Y	Average Normal Pulse	61.27	68.04	68.93	73.04	73.52	
	M. V.	3.93	3.33	3.53	3.40	3.18	4:30 p. m.
Z	Average Normal Pulse	56.06	59.07	58.04	59.80		
	M. V.	3.09	4.59	3.11	2.62		2:00 p. m.

turn, accumulate and prove more and more serious as a "critical stage" in the learning is approached.

These daily variations in attention and effort are related to learning in yet another way. As we have said, they are synonomous with fluctuations in efficiency. On the bad days less work can be done, more mistakes are made, unpleasant feelings accumulate, a distaste for the work is developed, and the writing must be done in a more primitive way. The best thing the learner can do when these lapses in efficiency occur is to drop down to a plane of work low enough to enable him to work successfully. Then the habits already formed will be rightly exercised and strengthened and no education in error will result. The strong tendency to rush ahead at the bad periods, and on the off days to try to make up for the lowered efficiency, must be held in check.[1] There were many clear cases where the score for a particular day was raised by such a rash application of effort, but it does not pay. The wrong tendencies and habits thus formed will sooner or later have their revenge.

An important question for learning is, of course, how far the daily fluctuations in spontaneous attention and effort can be influenced or controlled by the incentives to *voluntary* effort over which the learner and teacher have control. While the indications are that something may be done in this way to regulate and control them (compare p. 148, note), the surest remedy seems to be improvement in the learner's general neural tone, induced by sleep, rest, exercise, food, change in attitude, mood or what not. The present study has forced upon the writer the conviction that no practice or study is entirely economic unless the learner is in perfect mental and physical condition. Work or study while the learner is fatigued is not only worthless so far as progress in learning goes, but is apt to be a positive hindrance.

(e) Fluctuations in Attention and Effort at Different Stages of Practice.—More important again than the daily fluctuations in attention and effort were the variations which occurred at different stages of practice. Of these there were two kinds. (1) A lapse in spontaneous attention and voluntary

[1] Even amateur writers seemed to have learned this lesson, and it is second nature with the expert; but for the learner it is a real problem and of vital importance. The progress he makes in developing the habits which are to constitute his skill will depend largely upon the attitude he assumes toward these fluctuations in efficiency.

effort occurring at irregular periods throughout the practice and lasting in our experiments from three to eight days, short periods of relaxation which might or might not be immediately followed by a lapse in the efficiency of the effort put forth. (2) A regular and much longer lapse in spontaneous attention and voluntary effort occurring at definite levels of advancement and regularly tending, as soon as noticed by the learner, to be followed by a period of nervousness or lapse in the efficiency of voluntary effort.

(1) The Irregular Lapses.—The fact that there was a regular decrease in pulse rate at certain irregular periods of the practice (the "breathing places" in the learning curves, where no measurable improvement was made) strongly suggests that the learners did not, at such times, exert themselves as much as normally. This is clearly indicated in Table VI, which gives the average rise in pulse, above the normal, for all the short periods of non-improvement, placed opposite the average rise in normal pulse for the periods of improvement which immediately

TABLE VI.

	Rise in the Learning Curve.				Arrests in Learning Curve.			
	DATE.	No. of Days.	Ave. Rise in Norm'l Pulse.	M. V.	DATE.	No. of Days.	Ave. Rise in Norm'l Pulse.	M. V.
Y's T. M. Curve.	March 10-17	8 days	8.75	1.45	March 18-22	5 days	5.47	1.00
	April 6-15	10 days	9.34	1.81	April 16-21	6 days	4.97	1.98
	April 22-25	4 days	9.40	1.48	April 26-May 1	6 days	4.62	.88
	May 2-June 8	38 days	8.30	1.75	June 9-15	7 days	4.60	1.12
	June 16-23	7 days	7.52	1.69	June 24-July 9	10 days	5.44	1.78
	July 10-17	6 days	7.70	2.16	July 18-23	5 days	5.40	2.02
	July 24-29	6 days	7.05	2.07				
Z's S. M. Curve.	March 20-April 4	16 days	7.80	2.50	April 5-10	6 days	6.42	1.35
	April 11-27	16 days	7.12	1.59	April 28-May 5	7 days	6.48	1.57
	May 6-26	17 days	7.35	1.56	May 27-June 22	18 days	6.81	1.25
X's S. M. Curve.	April 7-18	12 days	8.35	1.43	April 19-22	4 days	4.40	2.01
	April 23-24	2 days	9.15	1.52	April 25-May 5	12 days	6.88	1.50
	May 6-20	14 days	9.20	1.26	May 21-June 2	12 days	7.12	1.26
	June 3-20	16 days	8.40	1.31	June 21-22	2 days	5.10	1.55

precede these periods of arrest. With a single exception[1] there is a *lower* average rise in pulse for the "breathing places" in the curves than for the periods of practice where the learning curves show a rise (compare the learning curves, Fig. II, p. 20).

That this decline in pulse rate is indicative of a lapse in attention and effort was shown by the notes of the experimenter and learners. By comparing the notes of the experimenter for the days corresponding to the "breathing places" in the curves, striking sentences similar to those already quoted, to illustrate the lapses in attention and effort on particular days regularly occurred. When it is remembered that neither the learners nor the experimenter knew the score that was being made, that the experimenter's notes were written during the test, these descriptions of the outward signs of relaxation become strong confirmatory evidence of the lapses in attention and effort suggested by the drop in pulse rate.

The *learners* were not directly aware of these irregular lapses in attention and effort. The *ennui* stole upon them more or less unawares. Only after a certain accumulation had taken place did they become aware of their decreased endeavor. However, if we take the notes for the days corresponding to these irregular periods of arrest, we get additional proof for the lapses in attention and effort under consideration. The learners, in describing the difficulties met and telling how the work was done, unconsciously described the lapses in attention and effort shown by the drop in the pulse curve. Full notes for all the "breathing places" might be given in illustration. A few typical sentences from the notes for the third (compare p. 20, Fig. II, curve A, pulse 4.62) and last (Ib. pulse 4.60) "breathing places" in the T. M. practice of Y must suffice.

Notes for the third "breathing place" (April 26-May 1) in Y's curve:

On the 27th he wrote: "Much bothered by capitals today. This was very provoking and probably affected the rate. The 'good feeling' about rapid and easy writing so prominent some days ago not present, although there were no instances of getting lost on the keyboard causing confusion. My effort was less than for the last few days, as I remember." (28th): "Seem to have just enough difficulty all the time

[1] The one exception was the "breathing place" which occurred in the last part of Z's S. M. curve (curve C, Fig. II) when he was on the verge of his second "critical stage". His notes for this period show that for the first two days of the period there was the usual lapse in attention and effort, which was, however, in this case, followed by stronger effort recklessly applied. This raised his pulse to 7.14, but there was no progress in learning because his effort was wrongly applied.

to constantly prevent any great speed. Did not get extra motives for maximum effort at any time during the test." (30th): "My interest in the copy, from some cause, seems to interfere with my writing. Had my attention too much on the sense of what I was reading and off the keyboard. Noticed the tendency to write fast and carelessly instead of slow and carefully, caused, I think, by the fear that I was going slow on account of the distraction of the copy." The day before and the day following this "breathing place" Y reported having tried harder.

Notes for the last "breathing place" (June 9-15) in Y's curve:

(June 9): "Did not get started at once and noticed many errors that I did not seem to be able to avoid. True, even after I did get up a better speed. Often noticed the tendency for the fingers to 'run away' with themselves and make all sorts of errors. I tried to check this but did not seem to be able to keep my attention on this sufficiently to avoid it altogether. Did not feel so wide awake as yesterday at any time during the test, or afterwards. General effort, probably a little below average. Did not seem to be able to keep the different things in mind so well as heretofore." (10): "Distracted at first and also again towards the last by people in the hall and laboratory. Effort is very irregular. Writing in general characterized by absence of recognition of correctness or wrongness. Vaguely thought I was making a number of errors which I only half noticed. Also aware of my inability to keep my fingers in proper place. They went by themselves and too fast to avoid error." (11): "Tried to keep the fingers back at first, then noticed a strong tendency following to go fast in the general direction of the correct key but too fast to avoid errors. I did not write apparently with an average vim and energy." (12): "Many distractions. Kept thinking of a number of outside things, which interfered considerably with both correctness and speed." (13): "Effort below average. Did not seem to get nerved up to the task at any time. Considerably distracted from thinking more or less constantly of outside things." (14): "A distraction was more or less present throughout. Don't think I wrote with an average enthusiasm." (15, start of rise): "Writing characterized by a greater than usual ease. The fingers seemed to go to their places more readily, the recognition of errors was more immediate and no loss of orientation occurred. The whole keyboard seemed to remain 'clear'. There was very little recognition of individual strokes that were correct, nor did the writing seem to proceed much by groups. It ran on in a continuous fashion until some particular difficulty demanded special attention."

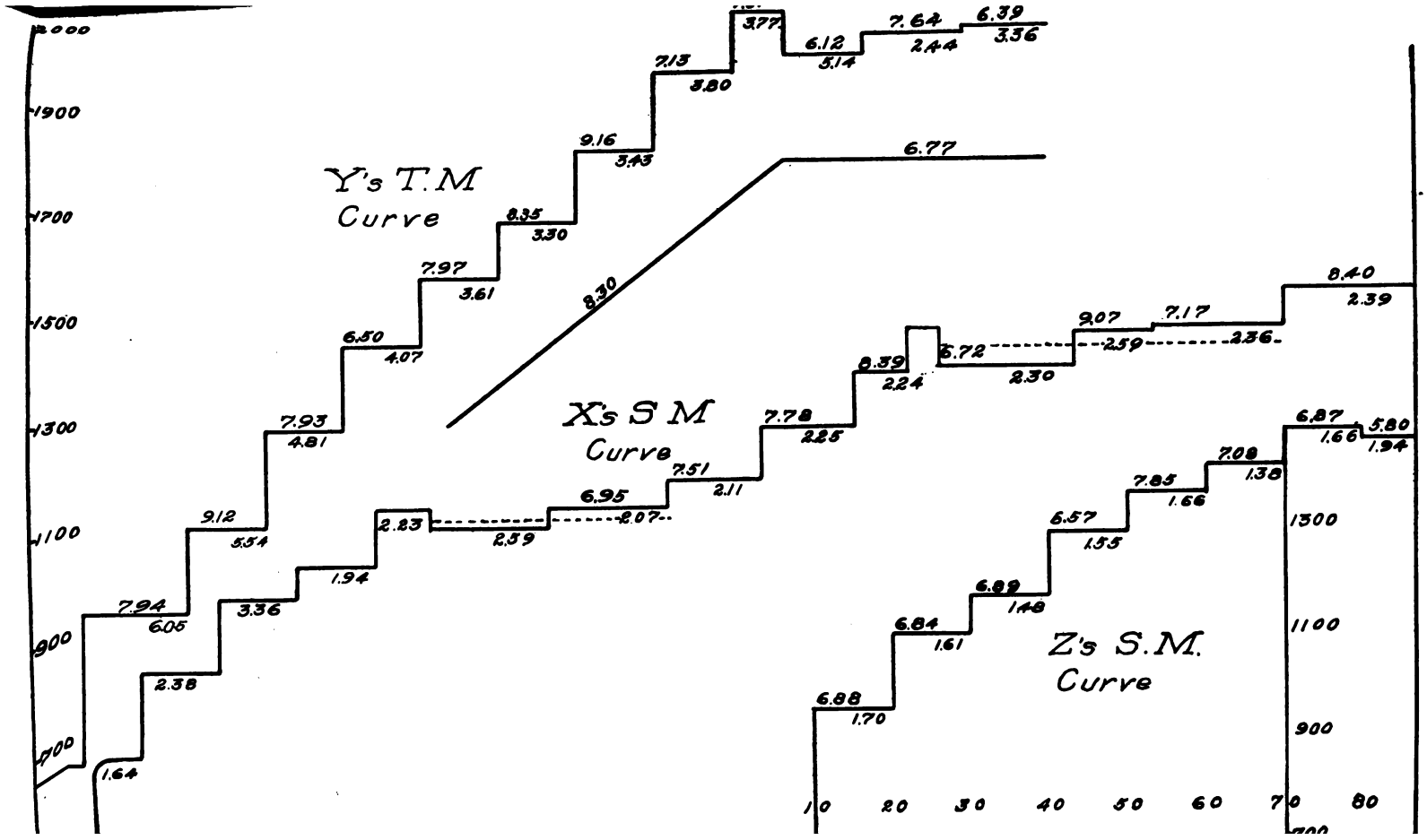
Of the many causes which operate singly or together to produce these irregular lapses in attention and effort, habit is one of the most important. As we have seen, each day's work has an influence on succeeding days. If for any reason the incentives to spontaneous or voluntary effort for a particular day have been low it will make it easier to work more lazily the next day. A number of influences acting to decrease the learner's enthusiasm will soon produce a marked lapse in attention and effort the effects of which regularly accumulate until broken up by fresh incentives to effort. These lapses were almost entirely (almost, not quite, compare p. 155, below) responsible for the "breathing places", or short periods of arrest in our learning curves. They may occur at any stage of the practice and are normally broken up, after six or eight days, by some special

incentives to effort which serve to shake the learner out of his lazy sleep. Only when they appear on the eve of a "critical stage" do they prove serious for progress as a whole. At such a time they may greatly aggravate the longer lapses which occur at these stages. Coming in conjunction with these more serious lapses in interest and effort they may *tend* to fix more strongly on the learner the habit of inattention to the work which the learning at the "critical stages" naturally brings on.

(2) Regular Fluctuations in Attention and Effort at the "Critical Stages" in the Learning.—It was determined that at certain definite levels of advancement in the learning there regularly occurred, or strongly tended to occur, a marked relaxation in attention and effort, a spontaneous turning away of attention from the details of the work, *a lapse in spontaneous attention,* which was regularly followed by a relaxation in voluntary attention or effort and a little later, when the consequent lack of progress was noticed by the learner, by greater effort wrongly applied to the work, effort which, therefore, made for retrogression rather than progression in learning.

These longer and more serious lapses in attention and effort were revealed as usual by the pulse records taken while the subjects worked, by the learners' daily notes, and by the number and kinds of errors made at the different stages of practice. For long periods of practice (the "plateaus" in our learning curves), the pulse curve showed, in every case, a marked decline, the percentage of errors increased, while the introspections of the learners showed that attention strongly tended to drift more and more to the capricious and irrelevant associations, which at these stages more naturally and persistently tended to intrude themselves upon the learners.

The evidence for these longer lapses in attention and effort furnished by our pulse records is shown in Figures II (page 20) and XV. The curves in Fig. XV represent in a diagramatic way the progress made by our learners in both methods of learning. They are all drawn on the same scale. The time or number of practices is shown on the horizontal axis. The skill or rate of writing, in strokes, upon the vertical axis. The horizontal parts of the curves show (when measured by the vertical axis) the average number of strokes made each day during the period of practice indicated by the length of the sections in the horizontal direction. The vertical lines in the curves are mere


Y's T.M
Curve
X's S M
Curve
Z's S.M.
Curve
8.30
6.77
1900
1700
1500
1300
1100
900
700
1.64
2.38
3.36
1.94
2.23
2.59
6.95
2.07
7.51
2.11
7.78
2.25
8.39
2.24
6.72
2.30
9.07
2.59
7.17
2.36
8.40
2.39
7.94
6.05
9.12
5.54
7.93
4.81
6.50
4.07
7.97
3.61
8.35
3.30
9.16
3.43
7.13
3.80
3.77
6.12
5.14
7.64
2.44
6.39
3.36
6.88
1.70
6.84
1.61
6.89
1.48
6.57
1.55
7.85
1.66
7.08
1.38
6.87
1.66
5.80
1.94
10
20
30
40
50
60
70
80

connecting links showing by their length the gain for the period. The figures set above the horizontal sections of each curve show the average rise in pulse, above the normal,[1] the figures below the horizontal bars the per cent. of errors for the period of practice indicated by the length of the horizontal lines.

As may readily be seen by a comparison of the figures and curves, there is in every case a higher average rise in pulse, above the normal, for the periods of practice represented by the rises (slow and rapid) in the learning curves than for the plateaus.

That this regular drop in pulse rate meant a lapse in attention and effort, is shown by the number and kinds of errors made at these stages, and by the learner's daily observation notes. The figures, placed below the horizontal sections of the curves in Fig. XV, represent the percentage of errors for the period and show that there is a gradual decline in the percentage of errors for all periods of rapid improvement, in accordance with the development of the general habit of dealing carefully with all difficulties as they appear (see pp. 69-71). But as a "critical stage" in the learning is approached, there is a marked rise in the percentage of errors. In every case proportionately more mistakes were made for the periods of practice represented by the plateaus than for the periods of rapid improvement. Moreover the kind of errors made showed the kind of variations in attention and effort which occurred. Whether there was merely a lapse in spontaneous attention and effort, or also a lapse in the efficiency of the effort put forth, or both, was clearly shown by the kinds and number of errors made.

The daily observations of the learners were more instructive still. They give the best bit of psychological evidence we have for the fluctuations in attention and effort under consideration. Not that the learners were directly aware of the relaxation in attention and effort. They only knew that at certain stages of the practice attention tended strongly to drift away from the work, that it was taken up more with outside interests, that they were less interested in the work at certain stages than at other

[1] No pulse figures appear on the first part of X's S. M. curve because no pulse records were taken in the first part of his practice, (see p. 14). The dotted lines through X's curve mark the average number of strokes made each day for the entire period. The lines under Y's T. M. curve with their corresponding figures show the average rise in pulse for the period of practice indicated by the length of these lines.

stages, less enthusiastic and the like. All this was minutely described by them; but that it meant that they were putting less energy into the work, as our pulse curves show, that it meant a relaxation of attention and effort, they did not know. If they thought of it at all or commented upon it in their notes, as they sometimes did, they merely said that because the work was now getting so much easier attention did not need to be focused so closely on the work as formerly. The natural spontaneous incentives to effort dropped out too gradually to be noticed by the learner, who worked along lazily and carelessly, quite unmindful of the fact that a relaxation in attention and effort had occurred. Like the lapses at the "breathing places" these larger variations in attention and effort were unconsciously described by the learners.

Quotations from the notes might be multiplied almost indefinitely, not only in illustration of the fact that such fluctuations as we are considering occurred, but as showing the innumerable ways in which the learning consciousness was modified by them. The notes purporting to give an analysis of the learning consciousness for these stages revealed two significant facts. (1) That the learner's attention more naturally and strongly tended to slight or neglect the *details* of the work at the stages where these larger fluctuations in attention and effort occurred, i. e., the specific associations developing at the time seemed to lose some of their drawing power for attention. (2) Attention tended naturally and strongly to drift away from the work as a whole. A few typical quotations from the notes will make both points clear.

In describing how the writing was done at the beginning of the word association stage, X wrote:

"I have now reached the stage where the letters do not have to be so diligently sought out and fixated upon by the eyes and attention as formerly, and I find that my attention wants to go somewhere else. There is a strong tendency to slur over the letters, and not locate them, even when they are not known. I occasionally catch myself striking letters which have never been definitely located or even indirectly seen. It takes special care to keep my eyes on the letters long enough. I seem to be getting lazy on this point. Because I do not now need to see the letters so sharply as formerly, the little attention still required to locate them is apt to be neglected. This tendency I think, is growing."

On another day he wrote: "I am getting decidedly careless about attending to the individual steps in the work. I slur over them in a sort of haphazard, careless way. I am less intent in focusing upon the steps of the work either because, with the short circuiting, many are dropping out, or I am getting lazy on this point and letting my attention go elsewhere. I now make many mistakes because I leave too

much to the automatic sense. I am getting careless with my conscious direction. When I strike the right balance on this point and can keep my whole attention on the business of directing my hands and fingers, I get along best." Z described this same fact in his S. M. notes. "My fingers," he said, "cannot yet surely find any of the keys except in the small easy words. Not even the last letters of the word are made by attending to their motor-tactual feel, but the tendency is strong to use visual location less and less, to neglect it far too soon. I know about where to strike without visually locating the keys, so do not feel the need of putting forth enough effort to carefully locate them. As a result many mistakes are made. It now takes special effort to make me use enough visual direction to properly guide my hands."

Typical quotations from the notes in illustration of our second point—that attention naturally and strongly tends to drift away from the work as a whole at certain definite stages of advancement—are the following:

"It has become quite a habit with me now," wrote X in his daily notes, May 4, "to attend to other things while I write. I find myself continually now not giving such close attention to the work as formerly. I have no trouble in getting my mind back on the work when I notice that it is off, but it naturally tends to leave the work. I have to battle with distractions now almost every day, not to do the work (I can now write very well and still think of other things), but if I let my attention go as it would, I cannot write so rapidly or well. Today I kept thinking of a number of outside things all the period. As I write along the most unheard of associations come up, associations that cover the entire range of my experience. In most cases no connection can be traced between anything in the writing and the thoughts that come up. Much of the time today I was carrying on a distinct side line of thought as I wrote. Distractions seem to be coming in for more than their share of attention of late."

Other typical notes for the period of practice representing the second plateau (April 19 to June 2) selected somewhat at random, are the following: (April 27): "Find that I can't make myself pay attention to the letters and particular steps of the work as I should. I am going at it more blindly it seems." (May 2): "Am now often bothered by distractions. Today kept thinking all the while about the meaning of the article I was writing. I experienced great difficulty in keeping my attention focused on the writing." (30): "I spend much of the time now with extraneous things. Today I kept thinking that I had moved the tambours and wondering whether I was getting a record, etc. It takes constant watching for me to hold attention on the work." (4): "Caught myself three or four times today playing along and not half doing my best. When I noticed this I 'spurted up' but could not keep up the pace. I continually dropped down to an easy gait of writing and let my attention wander to outside interests."

Typical sentences from Z's notes when he was contending with the second "critical stage" encountered in his learning, are the following: "I now often catch myself attending to other things while I write." (May 19): "I now often find myself not attending to the work as closely as formerly, why, I do not know. I have no trouble to get my mind back on the work when I notice this, but it continually keeps getting off." (May 20): "I have to battle with distractions now every day." (May 24): "Caught myself going very slow today and noticed that I was half unconsciously looking up a place on a map where I had applied for a position. I am much vexed to see how often part of my attention is thus busied with other things when I am supposed to keep it all on the work."

The cause of these longer and more serious lapses in spontaneous attention (or interest) and in voluntary attention (or

effort), is now evident. The plateaus in our learning curves where these fluctuations occur appeared or tended regularly to appear at certain definite levels of advancement as we have seen (compare description of Learning Curves, p. 21). Our analysis of the learning consciousness has revealed the fact that these are the stages where certain special associations or groups of special associations are being finally perfected. It has also shown that all special associations are perfected very slowly and that as they approach perfection, i. e., are becoming automatic, they become harder and harder to hold in attention. In other words, attention naturally tends to slight the *details* of the work where a special association (letter or word) or group of such special associations are becoming automatic and the work as a whole when the chances for improvement become slight or impossible. The more serious lapses in attention and effort at the "critical stages" in the learning where special habits or groups of special habits are being finally perfected are, therefore, brought on quite naturally by the nature of the learning or way in which the special habits are formed and perfected.

In the early stages of learning, where many elementary associations were in their first stages of development and where, consequently, many short cuts in method were possible and easy to make, no lapses in attention and effort occurred. The associations were in their first stages of development where improvement was rapid and easy. This kept attention closely focused on the *details* of the work. Moreover, rapid improvement was being made in many departments of the work which made progress in learning rapid. This marked success kept attention focused on the work as a whole. It was thus regularly pushed ahead to a higher and more economic way of directing the work as fast as legitimately freed from the oversight of details. The strong incentives required for keeping attention focused on the work and forging ahead were furnished by the rapid progress and success. The pleasant feelings attending the success serve as a sort of magnet for spontaneous attention or interest. Furthermore, as long as progress is rapid, spontaneous attention is easily supported by efficient voluntary effort.

With the continuation of practice and gain in skill all this is changed. The elementary habits get further along in the course of their development; and, as attention naturally tends to drift away from every association or detail of the work as it

becomes automatic, these associations soon lose their natural drawing power for it. Furthermore, the interest and effort given by successes in other departments of the work likewise grow less, because fewer adaptations remain to be made in these departments of the work, and because those still to be made become harder and harder to make as skill increases. The tendency to relaxation caused by the final perfection of an *elementary* association (letter association) is, therefore, more easily overcome than the tendency to relaxation occasioned by the final perfection of a special habit of a higher order (word association). In the former case the difficulties occasioned are caused by a lapse in attention due to the perfection of a single association and come at a time when the incentives to spontaneous attention and effort are constantly rejuvenated by the rapid improvement made in the early stages of the learning. Later, when higher-order habits are being perfected there are fewer incentives to attention and effort due to general improvement or success, the process of perfection is itself, in all probability, slower and more difficult, and each special (word) association receives individually a less frequent repetition—all of which make the tendency to relaxation stronger than ever. In other words, the "critical stages," or natural lapses in attention and effort, become more and more serious as an expert skill is approached. At the second or third "critical stages", if so many occur, stronger artificial stimuli are required to keep attention focused on the proper details and on the work as a whole.

This fact, then, that attention tends naturally to drift away from every activity or special association as it becomes automatic, and drifts away from the work as a whole as progress becomes slow, is responsible for these longer lapses in spontaneous attention and effort. This natural tendency is much augmented by the fact, several times mentioned, that the special associations are finally perfected very slowly and gradually, and that the slight attention which is so hard to give is absolutely necessary for their proper perfection. The learner must keep bringing his attention back to the work as it drifts away, which takes up much of his energy. When this was not required, all energy went into the work. Voluntary attention can, therefore, never fully take the place of natural or spontaneous attention. The learner at the "critical stages" has need for incentives that

make their appeal to spontaneous attention or natural interest.

The relation of these longer lapses in attention and effort to learning now becomes clear. No real progress in learning is made when these lapses in attention occur, because, as we have seen (pp. 92-95) new adaptations or forward steps in learning are made only when strenuous effort is properly applied to the details of the work. Throughout this study we have used the term "critical stage" to designate the periods of practice or stages in learning where these lapses in attention and effort occurred. When it is recalled that the lapses came at those stages of advancement where certain special habits or groups of such habits were being finally perfected, and that the learner's attention, at such times, tended naturally and strongly to slight the details of the work, even to drift away from the work as a whole, and when it is remembered that the special associations thus slighted must be carefully perfected to attain the higher skill, and that they *require some* attention for a *very long time* to be properly perfected, our reasons for the use of the term will become apparent. These stages in the learning will be seen to be more critical still when it is recalled that the learners, when the slow progress due to the relaxation of attention and effort was noticed, regularly tended to try to go too fast, pushing attention on to a higher mode of direction before the details could be taken care of automatically. At these "critical stages" one of three things will occur:

1. The learner may be caught unawares by the lapse in attention and effort and continue to work as carefully as usual, but more and more lazily until a habit of working lazily is fastened upon him. In this case there will be further perfection of the habits involved in the writing at that stage, provided mistakes are avoided. But the learner fails to push himself on to a higher plane of writing and continues to work lazily until his interest in the work has been permanently dulled by the almost imperceptible improvement.

2. There is more apt to go with the lapse in spnotaneous attention and effort a growing carelessness and indifference towards the work, which, when later the lack of improvement brings a spur to energy, leads to a reckless application of attention and effort and to practice in error with a consequent "breakdown" in the learning. The learner rashly tries to make up for the lapse in spontaneous attention by greater effort, but

neglects to give careful attention to the details, which only prolongs his plateau.

3. The learner may successfully deal with the special difficulties which the case presents, conquer every tendency to lag by the application of vigorous and well directed voluntary effort, and so carefully control his attention that the "critical stage" will be passed without a break in the continuity of his progress.

All these possibilities were realized in our experiments, as we shall see when we take up the explanation of the individual curves, but it should be pointed out here that the "critical stages" present difficulties which the learner, who does not know the real cause of his small progress, nor the best way to remedy it, has great trouble to overcome successfully. He *may* meet them successfully and do much to make up for the dearth in incentives to effort. But left to himself he rarely solves the problems presented in the best way. He has much trouble to make amends for the failure in spontaneous attention (or interest), because there naturally goes with it a simultaneous failure in voluntary attention (or effort) as hard to control as the tendency of spontaneous attention to desert the work as a whole. This disarms the learner of the only means at his command for remedying the defect. The learner is quite unable to change the natural condition induced, by a sheer act of will. He may try as hard as he likes, his energy mainly goes into the trying instead of into the writing. The most effective stimuli, those born of progress and success, are lacking. In fact the evil effects of the relaxation of attention and effort and growing indifference may be much aggravated and the seriousness of the "critical stage" much increased by the blunders which the learners, if left to themselves, are apt to make. The learner, at the "critical stages", has special need of the guidance and help of a skilled teacher, one who knows the nature of the difficulties encountered, how they can be most successfully met, and who, therefore, can give the needed direction and incentives to effort. The learner not only needs wise direction, but must be provided with such incentives to effort, emotional helps, interest in the higher phases of the work, etc., as will atone for the lapse in spontaneous attention and effort naturally brought on by the gradual perfection of the special habits involved in the learning.[1]

[1] Certain artificial incentives which proved helpful in our experiments in keeping the learners up to maximum effort, may be illus-

3. *Changes in Feelings, Attitude and Mood Correlated With These Variations in Attention and Effort.*

(a) Correlation Described.—It was observed by the learners that marked fluctuations in feeling and attitude occurred from moment to moment of every test, from day to day, and at different stages of practice as did the variations in attention and effort just described. A high degree of *spontaneous* attention was *always* marked by a pleasurable feeling tone; a failure in it by feelings of displeasure or disgust. The exercise of *voluntary* attention, also, when successful, developed a similar favorable attitude; and was always accompanied or followed by feelings of pleasure; if wrongly directed and unsuccessful, it aggravated the already unfavorable mood and was followed by feelings of displeasure.[1]

In fact the correlation between the learners' general affective tone or attitute and the fluctuations in attention and effort described above, was so close that if one had a complete and accurate record of the changes that occurred in the former, he would have an accurate criterion of his progress and efficiency. The learner's mental attitude and general tone of feeling was a true index of his progress and ability to do.

(b) Role Played by the Feelings in Learning Typewriting. —That feelings of pleasure and displeasure run parallel with

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trated by the following generally typical examples from the notes of Y:

"The fact," wrote Y, Apr. 25, "that I am more or less conscious of my rate, helps me keep in mind constantly the demand for maximum effort." "The fact that I have the task each day of stating how much effort was put into the writing, I feel sure, makes me keep in mind more constantly the need of doing my best. I am sure this made me try harder today" (Y, April 30): "The idea of wanting to fill the page was present again today and urged me to greater endeavor, but not so prominent as yesterday" (Y, May 28). Two days later he was given a much longer sheet and wrote: "The idea of seeing how much of this long sheet I could fill occurred several times during the test and urged me to greater endeavor." "The idea of filling the page occurred several times again today and noticeably effected my effort and the emotional attitude. It was fun to write today, apparently not because I was going fast, but because I was going to fill the page" (Y, June 1). "Idea of time being nearly up came in twice today and naturally increased my effort" (Y, June 7). On June 20, after describing certain methods recently adopted to make the writing go better, i. e., to avoid certain mistakes, Y wrote: "Thinking of these things seemed to keep me more widely awake. They gave occasion to keep more constantly in mind correctness and maximum speed. The 'going to sleep' or 'off guard periods' which now so often occur in the practice were prevented."

[1] In a few instances (the "critical stages" in the practice sentence writing) the learner's interest in the work was irreparably paralyzed, by the irritating drudgery which the writing involved.

successful effort and its opposite is a matter of every day experience and needs but to be mentioned.[1] The role of the feelings in successful learning is perhaps not so clear and deserves a word or two of comment.[2] Two questions naturally arise: (1) What is the meaning of the perfect correlation between the fluctuations in attention and effort previously described, and these changes in feeling and attitude? (2) What retroactive effect have these fluctuations in attitude and feeling upon the variations in attention and effort that went with them?

It by no means follows that the relation between these changes in feeling and attitude and the fluctuations in attention and effort is casual because the parallelism is perfect. Whether the feelings and mental attitude of the learners give rise to the fluctuations in attention and effort and the consequent failure or success in writing, or whether the fluctuations in attention and effort cause the changes in feeling, or whether both are joint effects of a still more fundamental cause, is a matter with regard to which it is impossible to make a general statement. In many cases the feelings and the failure of attention were clearly joint effects of certain health conditions. A good physiological tone not only gave rise to, or increased, the pleasant feelings, but made possible the proper use of attention and effort. In other instances a change of feeling clearly followed the variations in attention and effort and the resultant failure or success in the work. We find many sentences like the following in the notes: "At times I get very much discouraged and disgusted, but when I get a good period, as I often do, where I can write easily and fast, it encourages me and makes me feel good. I get thoroughly disgusted when a tangle comes" (Z, Apr. 20, practice sentence). "Before beginning the test today I glanced at the long sheet of paper which I knew I had

[1] For lack of space the learners' accounts of the feelings that were dominant during the good periods of writing and on the good days and those prominent during an off period or day as well as their descriptions of the feelings that paralleled the stages of successful practice and the larger lapses in attention and efficiency must be omitted. And while, as has been said, "Every one knows that feelings of pleasure and displeasure run parallel with successful effort and its opposite," the bringing together of what the various learners said on this point and the study of their notes has convinced the writer that we have not begun to realize the importance or significance of this common fact. It is a matter of such common observation that, like the beauties of nature, it is taken as a matter of course and its meaning and significance not even suspected.

[2] It was previously pointed out (pp. 71-73) that progress in the mastery of typewriting brought with it a permanent interest in the

to fill and became disgusted with the whole experiment. Soon after beginning to write, however, I had a remarkably good period, a brief period when all went easy and well. This made the work seem distinctly pleasurable and I felt good after that." Other cases were described where the feelings did not so clearly follow the fluctuations in attention and effort. A few cases were described where attention had to work successfully (or unsuccessfully) for some time before it noticeably affected the learner's attitude or mood.

These observations are, of course, too incomplete to enable us to say anything final as to the relation between the fluctuations in feeling and those in attention. So far as they go, they show that the feelings do quite as much towards inducing and emphasizing certain fluctuations in attention and effort as *vice versa.* In general, success always heightened an already present pleasant feeling or caused it to appear in consciousness. Failure and mistakes always aggravated the unpleasant feelings already present or made them appear. The influence of the learner's general physiological condition on both can hardly be overemphasized. Those psychologists are probably not far wrong who consider the feelings as a sort of thermometer which somehow registers the rise and fall of the learner's general psychophysical efficiency. This would explain why rapid progress and increased ability to do were always accompanied by pleasant feelings and a favorable attitude and mood. Pleasant feelings and an attitude of wrapped attention and interest would mean increased psycho-physical power, unpleasant feelings and an unfavorable attitude or mood a decrease in such power. The general fact that the learner's feelings were such a perfect index to the way their attention worked would then have a rational meaning.

But what about our second question, the retroactive effect of pleasant and unpleasant feelings upon the learner's ability to do and to improve? In answering our first question we have

work. That is, as the subjects learned to write with ease and facility they came to enjoy the work more thoroughly. The expert keenly enjoyed the mere mechanical writing movements, because, as she said, "they can be so easily and perfectly made." For our learners the first general pleasure seemed to come from the fact that they were improving, learning to write, or accomplishing what they had set out to do. Later they came to take a keen interest in the mechanical movements themselves and enjoyed their feel. This general practice effect or habit, which is so vital for learning and of general theoretical importance, should be carefully distinguished from the fluctuations in feeling and attitude here discussed.

already answered this in part. Pleasant feelings had undeniably, in our experiments, a stimulating and helpful effect upon every part of the work, unpleasant feelings a depressing, retarding effect. Pleasant feelings produced something like an increased irritability in the neural basis of every psycho-physical activity in operation at the time. Success brings pleasure and the pleasure spurs the learner on to greater effort and more successful work. An unpleasant feeling tends to interrupt the natural, easy and correct movement of attention by taking forcible possession of consciousness and dominating it. Instead of consciousness being focused on the details of the work, it is filled with unpleasant feelings, which not only take attention off the details of the work, but create a "set" of mind unfavorable for the work.

In all moderate degrees unpleasant feelings serve as a distraction and produce, or further aggravate, a failure of attention. If exceedingly severe, they may, however, serve as an incentive to efficient effort and thus entirely counteract their usual effect. That is to say, one's mistakes or the unpleasant feelings which follow, may in rare cases, serve to arouse the learner to greater voluntary endeavor and so prove advantageous. Pleasant feelings always seemed to stimulate the right flow and movement of attention and, therefore, made every part of the work go better. Every increase in effectiveness caused more pleasure, it seemed, and the pleasurable feeling gave, in turn, the proper "set" of attention for still more easy and successful work. The learner could try both harder and more effectively when he was feeling good. He had to waste no effort in trying. Only when success led to complacent self-satisfaction and slackened voluntary attention did the effect of the pleasant feeling become disadvantageous. When it lessens effort to a considerable degree, its unconscious helpful effect may be more than counteracted. In our experiments, however, this never occurred. All pleasant feelings attending the success had a helpful reactionary effect on the work.

(c) The Accumulation of Feelings and the Formation of Attitudes and Moods.—One additional fact should be mentioned. It was found that a good moment or two in the early part of a test gave the learner a favorable mental attitude or feeling tone which often persisted for the rest of the test. As one of the learners expressed it (Z, May 22, practice sentence notes): "I

started today with a feeling of disgust. I was afraid I would go to pieces again like yesterday. When I found that I could write well, I began to feel better and wrote with more enthusiasm. Towards the end of the test I could put more enthusiasm into the work and write easily because of my early success."

But not only did the sensations which accompanied the variations in attention and effort accumulate during a test, and give a sort of mental attitude or mood for that test as a whole, this total effect is held over in a measure until the next day, giving to consciousness a characteristic "set" for the test that day. We find many sentences like the following in the notes: "Felt better before I started today, because I did so well yesterday," and similar ones for unfavorable conditions. If something does not occur (several good minutes in a test or a good day) to break up a mood of depression thus begun, the work of the day will only serve to solidify the already unfavorable attitude. In other words, the feelings accumulate; the lesser unpleasant feelings associated with the short periods of fatigue that cause a temporary distaste for the work to form the learner's general attitude towards the work for any day, the latter to form the longer and more intense periods of *ennui* and aversion to the work predominant at the "breathing places" and "critical stages".[1]

In the light of this fact and the effect which failure and unpleasant feelings have on learning, the danger to the learner of study or practice when interest has failed, or when he cannot succeed, is clearly evident. Practice or study at such a time simply makes the learner push himself into the longer and more serious periods of *ennui* (and the mistakes and arrest that go with it), characteristic of a "critical stage," developing a general attitude or feeling tone which may permanently retard or arrest his progress. There is much in our results that speaks strongly in favor of what is generally considered the artist's method of work. The artist or genius works hard and long when the fit is on; then lounges until it is again profitable to work. *The most economic learning would seem to demand that the learner work only when he can enjoy it and succeed,—and to wait until he can.* It is then that old associations are most rapidly perfected and that new economic short cuts in learning are made.

[1] The following quotation is typical: "My feeling attitude has changed a little for the better the last few days. I never hated any-

C. SUMMARY OF INFLUENCES BRINGING ABOUT THE FLUCTUATIONS IN THE LEARNING CURVES.

1. The Daily Variations.

After what has been said in the last few sub-sections about the factors and conditions influencing learning and rate of work, our explanation of the variations in our curves may be brief. The rate of work (and by inference, the rate of the learner's advance in skill) on any particular day is dependent on the joint action of a number of objective and subjective factors, the former owing their efficiency chiefly to the change which they bring about in the latter. Of the objective factors the most important in producing variations in the daily score of the regular learning tests was the unavoidable difference from paragraph to paragraph in the matter to be copied. Other outer influences, though efficient, were in large measure under control and, therefore, of infrequent operation. Of an intermediate character, but of dominant importance, were fatigue (especially that from general causes) and other physiological and hygienic conditions. More strictly subjective factors influencing the score were: (1) Differences in the amount of relearning and warming up which were necessary, or which actually took place, and the learner's adaptations to these factors for that day. (2) Fluctuations in spontaneous and in voluntary attention, with attendant changes in the intensity, in the direction, and in the efficiency of the effort expended. (3) Changes in feeling and emotional attitude, occurring in complicated relations of interaction with the changes in bodily condition and the states of attention just mentioned. As particularly liable to lead to a low score either for the day or a period of greater length, should be noted a tendency to try to make up for previous slackness by special effort with attention on speed, which led to error and the cultivation of false associations and brought many evils in its train.

2. The Breathing Places.

The "breathing places" in our curves, while they might be prolonged, and in rare cases caused by such a careless, wrong application of strong voluntary effort, were chiefly caused in

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thing so much as this practice sentence writing. Today I do not feel so much aversion to it because I have gotten along so much better the last few days. Doing it right and well makes me feel good and anxious to get back to the work next day." (Z's notes, May 17).

our experiments by the irregular lapses in spontaneous attention and effort above described. A variety of influences operated in producing these irregular lapses in attention and effort. As one of the most stable of these factors and certainly the most significant for learning may be mentioned habit and the learner's general attitude. Anything that retards success temporarily, that dampens a learner's ardor or interest and enthusiasm, and so takes away some of the spontaneous or voluntary incentives to effort, brings about a temporary lapse in attention and effort which by the law of habit is prolonged until broken up by some special incentives to effort.

As a third, and perhaps less frequent factor entering into the causation of the "breathing places", may be mentioned the daily fluctuations in efficiency occuring in complicated relations of interaction with these other causes. The subject may, on some particularly good day, have made an unusually high score and developed a method of writing far in advance of any previously used. He can on the following day do the work in the same manner again, if in good condition, because he can as a rule repeat any act voluntarily which he has once performed.

But to do the writing on this high plane requires all his attention. For several days attention will be able to make no new adaptations or additional short-cuts in method because it is wholly taken up with the work. It takes some time for the new way of writing to become sufficiently automatic to allow part of the attention to forge ahead in quest of more economical methods. The forward step having been made on a good day, when the subject's highest efficient effort was employed, he must for several days put forth a maximum effort even to hold the vantage gained on the good day. If for any reason he becomes slack in his effort or careless there will be a drop in his score, perhaps for several days. Moreover, after such a forward step in method has been taken the learner may for some reason meet a number of off days, when his "ability to do" has for some reason been so much lamed that he not only is unable to increase his score on succeeding days, but often falls below his previous records in spite of all he can do. Nor is this all. The learner on such a bad day was naturally tempted, as we have seen, to push himself along too fast. He feels that he is not doing as well as he has done before and in his eager desire to increase his speed and keep up his score he fails to direct his attention properly, and

literally crowds himself into all sorts of mistakes. He fails to give the attentive direction, which the writing for him in that condition and stage demands; the result is confusion, mistakes, practice in error, the evil effects of which must be overcome before further improvement can be made. This means that the learner must go slower and give extra attention to certain details of the work until the interferences, thus developed, have been eliminated; it means that the writing must be done for a time on a lower plane, and that the score for these particular days will be lower than for previous days. There can be no measurable improvement until these mistakes have been corrected; no new adaptations, until they have been fully overcome. These nervous spells, or periods of diminished attentive efficiency—no matter how induced, by the learner's mental or neural condition, by his past mistakes, by habit, or the natural conditions of the learning—coupled with the daily lapses in spontaneous and voluntary attention may thus serve to help keep down the score for several days.[1]

3. The Plateaus.

To understand our plateaus the following facts, already fully described in earlier sections, must be borne in mind:

1. There is no regular time order in the development of the special habits involved in the mastery of typewriting. They developed simultaneously and literally perfected each other. During the plateau practices there was no further development of the elemental habits preparatory for use as elements in the higher-order habits, there was genuine arrest.

2. The plateaus appeared, not after a certain amount of practice had been taken, but at definite levels of advancement.

3. At these same levels of advancement there regularly occurred lapses in attention, relaxations of interest and effort, revealed by the introspections of the learners, by the marked increase in the percentage of errors and in a striking way by the regular drop in the pulse rate.

4. These lapses in spontaneous attention and natural effort tended regularly to be followed by a rash misapplication of voluntary effort as soon as noticed by the learners.

[1] Additional evidence in favor of this interpretation of the "breathing places" is to be found in the fact that they often followed periods of sudden and rapid gains, as may be seen by referring to the learning curves, Fig. II, p. 20.

5. The "critical stages" did not prove equally serious for all learners. In some cases the difficulties which they occasioned were so successfully dealt with that the plateaus were eliminated.

It appears, therefore, that the plateaus in our curves do not represent periods of incubation, where certain elementary habits make substantial gains, preparatory to their organization into higher-order habits, they are: (a) Resting places in the learner's interest and effort; or (b) "breakdown" stages caused by excessive effort wrongly applied. They represent either a failure in attention and effort, naturally produced by the nature of the learning, or a period during which attention and effort are wrongly applied, where mistakes are multiplied and where subsequently the evil effects of practice in error are being slowly overcome and right habits of attention and execution regained. They appear at those stages in the learning where difficulties are unsuccessfully met, and were regularly accompanied by unpleasant feelings, an attitude of carelessness, growing disgust with the work, all of which tended to further restrict or inhibit the development of the associations to be formed.

Two questions naturally arise: (a) What happened on the conscious side during the plateau practices and what occurred when there was a rise from a plateau? (b) How far are plateaus a necessary feature of the learning process; may they be profitably and successfully eliminated?

(a) The Rise From a Plateau.—It has been generally held (compare *Psy. Rev.*, Vol. VI, p. 358, also the Garman Memorial Studies in Philosophy and Psychology, Boston, 1906, p. 306) that the special habits involved in the mastery of such complex feats as learning a Foreign Language or Telegraphy, were slowly developed and perfected during the period of monotonous practice represented by a plateau, even suggested that the plateaus were necessary for such development and that after a certain amount of such uneventful practice the elemental habits would more or less suddenly shoot together into new combinations, which, because of their greater efficiency, caused the marked increase in skill pictured by the sudden rise in the learning curves. This explanation of plateaus is based almost entirely on inferences made from objective facts and like so many other psychological deductions made from objective data does not fit the facts. The only sure way to find out what is happening

during the plateau practices or to find out the significance of plateaus for learning is to go to consciousness itself and find out what is actually taking place during these periods of monotonous practice or work. Our analysis of the learning consciousness for typewriting, gave no evidence whatever in favor of the explanation of plateaus just mentioned. What then is happening during these periods of uneventful practice and what occurs when there is a more or less sudden rise from a plateau?

Though the facts revealed by the learners' daily notes for the plateau practices were all significant and instructive, it is impossible to give a complete analysis of the learning consciousness for these periods. What happens on the conscious side, depends, of course, on the cause of the particular plateau in question. If it has been caused by a simple lapse in attention and effort the learning consciousness remains comparatively simple and is easily analyzed. There will be a gradual turning away of attention from the details of the work and a drifting away from the work as a whole, and no progress will be made save that which comes from a further perfection of the then present methods of work. These associations will continue to grow *very slowly*[1] if the practice is kept free from mistakes. The learner is simply caught by the law of habit and fails to improve because new adaptations or "short cuts" in method can not be made unless attention is kept vigorously and properly applied to the work. If at any time during such a plateau greater effort be carefully applied to the details of the work new adaptations will be unconsciously fallen into as we have previously pointed out, and the learning curve will show a consequent rise, the rise from the plateau meaning that new adaptations have been made in one or more departments of the work.

If, on the other hand, the lapse in attention is followed by a growing carelessness, its usual associate, and a little later, when the learner becomes aware of his lack of progress, by greater but misapplied effort, the learner's consciousness becomes very eventful and complex. All sorts of interfering associations and tendencies will be developed in masses, and much careful work must be done before there can be a rise from such a plateau. Proper habits of attention (applying it more carefully to the details of the work) must be regained, and the many psycho-physical interferences developed by the practice in error,

[1] More slowly than if perfected in conjunction with the development of higher-order habits (compare p. 88).

must be carefully overcome before any measurable progress can be made. The general habit of carefully mastering every difficulty as it comes up, which at such a time has been set aside, must be carefully revived. The associations then in process of final perfection, which are being slighted by putting attention on speed, must be carefully practiced until all the interfering habits and tendencies have been eliminated. By the former practice in error a whole new set of habits and feelings have been built up which must be replaced by correct habits of work and pleasant feelings before any visible progress can be made.

But such gains are not shown by the learning curves. These at best give but an incomplete measure of the learner's progress and tell us nothing about his actual procedure in the learning act. While we can get no better general index of a learner's improvement than an accurate measure of his "ability to do", yet many factors important for *future* progress in learning, factors which determine a learner's efficiency and capacity for learning at that future stage, make no measurable manifestation of themselves in the curves. When the learner is gradually learning how to deal successfully with the daily and momentary fluctuations in his efficiency and is learning to direct and apply his effort to the details of the task so as to correct or overcome some old or recent mistake, when he is making the necessary adjustment for dealing most economically with some of the special difficulties which the larger fluctuations in attention and effort call forth at the "critical stages", when the cumulative effects of these smaller and larger fluctuations in attention and effort are broken up by successful practice, the learner is making important gains which do not affect the learning curves or add aught to the actual development or perfection of the associations to be formed. But the things the learner does at such a time, nevertheless, mean gain for him since they *must* be done before further development of the associations to be formed can occur. The rise from such a plateau not only means that all this has been successfully done, but that new adaptations have been made in one or more departments of the work.

(b) Are Plateaus a Necessity?—The facts, old and new, seem to the writer, to warrant the following general statement. In all simple learning, where only one or at most a simple group of special associations are to be acquired no plateaus should occur. All improvement must come from the gradual perfection

of a few specific habits, and the progress in learning should be like the growth and development of a single association, rapid at first and becoming more and more gradual as perfection is approached. In all complex forms of learning, on the other hand, where many specific habits are to be formed and where simple elemental habits are continually reorganized into higher-order habits plateaus naturally tend to occur and often do occur at those stages of advancement where certain elementary habits or groups of such habits are being finally perfected; because at these stages in the learning attention tends, as we have seen, strongly and naturally to drift away from the associations to be perfected and from the work as a whole. This means arrest of progress and the development of all sorts of interfering habits and tendencies, difficulties which become harder to prevent with each succeeding "critical stage".

Can the difficulties peculiar to the "critical stages" be successfully overcome and the consequent plateaus eliminated? Since we have found nothing in their causation that makes them a final or necessary part of the learning we conclude that they can. If we knew what associations were to be formed in the different fields of learning and hence where the plateaus tend to appear, so that we could properly guide the learners at these "critical stages" and provide such emotional helps and incentives to effort as would compensate the ebbing of immediate interest or cessation of effort, naturally brought on by the nature of the learning at these stages, there would be no arrest of progress until all possible adaptations and short cuts in method had been made and the highest-order habits or most direct methods of work attained. We conclude, therefore, that plateaus are not a necessity, even in the most complex forms of learning, as is, we believe, generally assumed, and give in further support of this statement the fact that *some of our learners did of themselves successfully overcome the difficulties encountered at some of the "critical stages" in learning to use the typewriter* and the further well-known fact that in learning such complicated things as playing the piano, or learning a foreign language,[1]

[1] We give in further support of this statement the following unpublished result obtained by Dr. W. L. Bryan in his study of Learning French, made immediately after the study of Learning the Telegraphic language. Dr. Bryan when asked about this point, said: "No plateau was experienced in that study though a high degree of proficiency was reached. Neither was there any lapse of interest. The fact that great effort was put into the work throughout the study is shown by the fact that I broke down completely under the strain of the work and had to give it up."

many learners successfully conquer the difficulties presented by every "critical stage" and thus eliminate the plateaus. The "critical stages" are, in all probability, a stern reality in all forms of complex learning, but our facts seem to warrant the general statement that a skilled and sympathetic teacher, one who knows what habits are to be formed in the learning he is to direct, and who, therefore, knows where the "critical stages" appear, might so guide his learners that their attention would be kept properly applied to the details of the work and few interferences formed. He might also provide such emotional helps and artificial stimuli, by arousing an interest in the higher aspects of the subject as would fully compensate for the natural lapses in interest and effort at the "critical stages". If the learner's interest and effort can be kept from lagging and kept properly directed there will be no plateaus.

D. EXPLANATION OF THE INDIVIDUAL CURVES.

With our facts all before us and their relation to learning pointed out the meaning of the fluctuations in our curves becomes clear. We shall confine ourselves in this section entirely to a consideration of the plateaus. The explanation of the daily variations and "breathing places" have already been given as fully as they were determined.

As previously pointed out the thing that is most likely to happen at a "critical stage" is a more or less serious relaxation of spontaneous attention and effort accompanied by a moderate degree of carelessness about the details of the work. The plateaus in our regular learning curves were all caused by this natural lapse in spontaneous attention and effort. Without exception there was a lower average rise in pulse for the plateaus than for the rises, slow or rapid, in the curves. (Compare Figs. II, p. 20, and XV, p. 140 and Table III, p. 111). The increase in certain kinds of errors at these stages, the learners' observation notes, and the behavior of the pulse and efficiency curves for the plateau practice (Figs. XII, XIII and XIV, pp.128-9) clearly showed that the drop in pulse rate meant a relaxation in attention and effort. Towards the middle of his long plateau, when he began to notice that he was making little progress, Y began to make excuses in his notes for his lack of improvement. He continually gave as the reason for the slow progress he felt[1] he was making that he

[1] It will be remembered that the learners were kept, as far as possible, in ignorance of their scores (see p. 13).

was now more careful about his writing, more particular about making mistakes, etc. But the drop in his pulse (compare Figs. II and XV and Table III), the fact that there was so much spontaneous turning away of attention from the work, and that his writing was *not* more correct for this period of practice, all go to show that a decline in effort and enthusiasm are responsible for his plateau.

But as we have seen the natural relaxation of attention and effort at a "critical stage" is apt to be followed by a period of work where intense effort is rashly applied, the attention being focused on speed instead of on the details of the work. X, who was strongly determined in his S. M. writing to do his best every minute and day, because of his extra interest in the experiment, tended strongly to overcrowd himself and so to misapply his energy. He escaped in a measure the tendency to relaxation because of the extra incentives to effort, only to fall into that of misapplied effort. This is shown by the fact that he made many more errors than Z, the other S. M. learner, and that his pulse rate decreased less during his plateaus than it did for the other subjects. That there was, nevertheless, somewhat of a lapse in attention and effort during his plateaus is shown by the fact that the average rise in pulse was less in every case for his plateaus than for the periods of rapid progress (compare Table III and Figs. II and XV), showing that there not only was a lapse in the amount of attention and effort put into the work but also a lapse in its efficiency. The middle periods for each plateau showed special evidence of this lapse in voluntary efficiency. That for a short period in the midst of his second plateau he tried exceptionally hard is shown by the unusually high rise in his pulse (9.07 beats). That his effort was now more unsuccessful is shown by the marked increase in the errors made and his notes for these days (compare Fig. XV, X's S. M. curve). There was a marked increase in that group of errors which indicated that excessive effort was being wrongly applied to the work. The same can be said for the middle part of his first plateau, though here the pulse record is less reliable owing to the fact that a method of getting a normal pulse had not yet been perfected (see p. 11). Part of the practice for the latter part of each of X's plateaus had to go to getting rid of the interferences caused by the wrong application of effort and the unintentional practice in error which it brought on.

That Y and Z, at the second "critical stage", where word associations were being perfected, also tended to become careless and to push their attention ahead too fast, is shown by the marked increase in errors for the period. Y's percentage of errors increased from 3.30 per cent to 5.14 for the beginning of his plateau. After he had been on his plateau for ten days, he became more careful about directing his attention and reduced his percentage of errors for the middle part of his plateau to 2.44. His notes for the period show that he was now giving special attention to accuracy. He made it a point to conquer this tendency to blunder and continually gave this as an excuse in his notes for the low score he thought he was making. Nevertheless his pulse curve for the period showed that less effort, than formerly, was put into the work, and comparing his plateau as a whole with the same length of practice immediately before, there were more mistakes. The tendency for attention to wander away from the work was so strong, the temptation to drop out the slight attentive direction still required for the details, and to put attention on speed so persistent, that the extra care was needed to prevent a "breakdown" in his regular learning, similar to that which took place in his writing of a practice sentence. For the last part of his plateau his percentage of errors rose again to 3.36 (compare Fig. XV, p. 140).

The periods of arrest in our practice sentence curves, were, with one exception, caused by this wrong and careless application of attention and effort. A glance at Z's pulse and learning curves for his practice sentence writing (Fig. VII, p. 112) will show that the average rise in pulse, above the normal, is very much greater for the plateaus than for the periods of practice where rapid improvement was made. The worst days of his practice, May 20 to 28, showed an average rise in pulse of 14.61 beats, while the eight days that marked the rapid rise from this plateau, June 15 to 24, showed only the normal rise of 8.71. Y's anger and disgust got worse and worse, until, towards the last of his practice he was fairly hammering the keys. He became so disgusted with the practice that he would not continue it. His pulse though low at first was abnormally high for the last part of his plateau (compare figures on curves, Fig. VIII, p. 113). But if we did not have the pulse records, nor the learner's daily introspections, the observation notes of the experimenter and the kinds and number of mistakes made would have shown that excessive effort was put into the practice

at these stages. Nothing but mistakes and arrest of progress could result from work of this sort.

Table VII, containing data for the practice sentence writing of Y and Z, is instructive in this connection and should be compared with the curves in Fig. VIII. It will be seen that the average rise in pulse is only 6.75 for the first part of Y's plateau. It then rises rapidly to the end of his practice. Z's pulse rate and errors rapidly increase until the latter part of his second plateau where there is a marked drop in both. This is followed by a still further drop in pulse rate, a decrease in the percentage of errors, and a rapid rise in his learning curve. His pulse for this period fell from an average rise of 14.61 to 10 beats, and a little later when rapid improvement set in to 8.71, showing, aside from the evidence furnished by the learner's and experimenter's notes and the record of his mistakes, that he was abandoning the excessive effort which he had been so reck-

TABLE VII.

	DATE.	Average Rise in Normal Pulse.	Character of Curves, or Progress.	Percent of Errors.
Z's Practice Sentence Writing, S. M. (61 Days.)	March 13-22 (10 days)	7.53	Early Rise in Learning Curve	3.06
	March 24-April 2 (8 days)	11.34	Forc'd Rise in Learning Curve	4.75
	April 4-17 (12 days)	12.41	First Plateau	7.55
	April 20-27 (7 days)	14.61	Plateau	6.55
	April 30-May 14 (10 days)	10.70	Plateau	5.51
	May 6-14 (8 days)	10.08	Plateau	5.10
	April 18-May 14 (20 days)	12.28	Whole Period, 2nd Plateau	5.95
	May 15-May 24 (8 days)	8.71	Rapid Rise From Plateau	3.04
Y's Practice Sentence Writing, T. M. (40 days)	March 6-15 (10 days)	6.82	Rapid Rise	5.60
	March 16-27 (11 days)	6.75	Plateau	5.13
	April 6-14 (9 days)	8.15	Plateau Continued	4.53
	April 15-29 (11 days)	9.37	Slight Forced Rise	6.54

lessly applying to the writing. But there was no immediate rise in his learning curve because the interferences built up by the wrong practice had to be overcome and right habits of attention regained before improvement could be made. Getting rid of these interferences continued his plateau several days. Y did not conquer his difficulties; he gave up the practice before there was a rise from the plateau.

The third thing that may happen when a "critical stage" in the learning is encountered is that the learner may contend so successfully with the difficulties of the situation as completely to eliminate a corresponding plateau from his learning curve. By a careful adjustment of attention and continuous voluntary effort he may keep his progress steadily continuous. How well a learner succeeds in making all his effort efficient and in resisting every tendency to lag depends, plainly, upon the learner and his stage of development. The "critical stages" become harder and harder to pass successfully as an expert skill is approached, and in the matter of dealing successfully with these difficulties great individual differences exist. Y succeeded better than either X or Z as regards the efficiency of such effort as he applied. Z was more successful in resisting the tendency to lag. But all our subjects learned, in a measure, to adjust themselves to the difficulties presented by the "critical stages". The first "critical stage" in the S. M. learning, which held X on a plateau for 33 days, Z mastered quite readily. His rate of progress was only slightly retarded and his interest and enthusiasm never failed (compare description of learning curves, pp. 20-1). He showed strong evidence, however, of being caught by the second "critical stage" which appeared in X's curve at the grade of skill (145 strokes per minute) attained by Z when his practice was stopped. For the last ten or fifteen days of his practice Z made little or no improvement, while his notes and the record of his mistakes, as well as his pulse curve, gave unmistakable evidence of a marked decline in effort and interest. X fell into the trap at each "critical stage" in his S. M. writing but successfully overcame the difficulties occasioned by the first "critical stage" in his T. M. learning. His intense effort, born of the extra interest in the experiment, made him an easy prey to the natural tendency to try to go too fast. This with a relative decrease in attention and effort caused, as we have seen, both his plateaus

in the S. M. learning. In his T. M. practice his progress was rapid and continuous throughout.

The fact that both X and Y, who had previously learned to write by the S. M., successfully met, in their T. M. learning, the difficulties presented by the first "critical stage" and so eliminated the plateau from their learning curves, is of special importance since it bears on the much mooted question of general discipline. From X's daily notes it appears that he was much influenced by seeing the more steady methods of work of Y, and unwittingly learned from watching him how much better it was to make haste slowly than to try to go too fast. That he learned much else in his sight method practice that proved useful in learning to write by touch seems clear (compare pp. 74-75, above). As his practice was stopped when he was writing at an average rate of 160 strokes per minute and since the second "critical stage" in the T. M. learning was not encountered by Y until he was writing at an average rate of 205 strokes per minute it is impossible to say whether X would have mastered the second "critical stage" also. So far as his practice went there was no sign of a decline in either effort or interest or of a plateau. Y, also passed the first "critical stage" without difficulty, but was caught by the natural lapse in attention and effort at the second "critical stage."

It seems significant that the plateaus in the practice sentence writing by the T. M. set in at exactly the same stage of advancement as they did in the regular writing, namely, when Y was writing at an average rate of 205 strokes per minute (compare curves A and E, Fig. II). In the practice sentence writing by the S. M. the plateaus encountered by X and Z appeared when a skill of 260 strokes had been attained, while the plateaus in the regular practice by this method occurred when X was writing at an average rate of 114 and 145 strokes per minute. This seems to suggest one of two things, either a third "critical stage" was ahead of the S. M. learners when their regular practice stopped, one more serious than any yet encountered, or a plateau due to excessive effort wrongly applied, while more apt to occur at the "critical stages" may, nevertheless, make its appearance at any time in the later stages of practice where several groups of special associations are in process of final perfection. This in all probability is the case though we have no further facts on this point.

VII.

GENERAL SUMMARY.

In the experiments above described two groups of data were obtained: (I) A set of individual tables and curves picturing the learners' progress (as measured by the criterion "ability to do" in the matter of typewriting) from minute to minute and day to day for the entire period of practice. (II) A group of objective and introspective data on the analysis of the learning consciousness, obtained with the view of getting such facts as would show not only what these curves stand for psychologically, but as would enable us to explain all their general and particular characteristics.

The important facts revealed by the tables and learning curves, our first group of data, are the following: (1) The curves belong to the usual type, that is, they rise rapidly at first and then more and more slowly as an expert skill is approached. (2) There are as usual marked fluctuations in efficiency from minute to minute and day to day—fluctuations which vary from subject to subject and for different sorts of practice. (3) All the regular learning curves show a number of short irregular periods of arrest, "breathing places" in their upward movement, lasting, in our experiments, from five to eight days. (4) Two of the regular learning curves and all curves for the "practice sentence" writing show one or more longer periods of arrest, actual plateaus where no improvement is made for a period of from 32 to 48 days. The "breathing places" or short periods occur at irregular intervals throughout the whole practice, and therefore, differ in nature and causation (pp. 139, 144, f.) from the plateaus which regularly occur or tend to occur at definite levels of advancement, at the "critical stages" in the learning.

The meaning of these purely objective facts is shown by our second group of data, the minute introspective analysis of the learning consciousness. This, as supplemented and verified by our objective data, showed: (A) The habits of various kinds and orders involved in the mastery of typewriting. (B) How these habits naturally took form and developed in the course of the learning. (C) The factors which helped or hindered in their formation and growth.

A.

In learning typewriting two groups of special habits are formed: (1) Habits of manipulation, or the specific psychophysical associations involved in the mastery of the writing itself. (2) Habits of control, certain more general or more purely mental habits formed in conjunction with the habits of manipulation—habits that are not involved in the writing directly, but rather preside over the formation of the special typewriting habits. In other words in learning to typewrite the learners acquire in addition to the habits of manipulation (the typewriting habits which enable them to deal more and more directly and economically with the particular problems presented by the writing), certain other habits which enable them to deal more and more successfully with the problems involved in the learning itself. Specifically the subjects learn: (a) How to "short circuit," or acquire to advantage the kind of habits which the mastery of the subject requires (p. 68); (b) How to meet and successfully overcome the many special difficulties which are characteristic of the learning of typewriting (pp. 69-70); (c) How to acquire and maintain a helpful attitude of feeling (pp. 71-72); (d) How to keep attention focused always on the writing (pp. 73-74); (e) How to use attention more and more effectively when applied to the writing. How better to use and economize voluntary effort, etc., (pp. 93-94).

The habits of manipulation, involved in the mastery of typewriting, are of all kinds and degrees, ranging from the most simple and elementary associations used by the beginner to the complex hierarchies of co-ordinated habits used by the expert. In beginning to write by the "touch" method, for example, an association must first be formed between the sight of each letter in the copy, or its mental equivalent (some form of inner spelling), and the thought of the exact position of the corresponding key, so that the sight or thought of the letter will call up instantly the exact position of the key. But this is only a necessary preliminary step in the process of getting the right finger to the key to be struck. This mental location of the key must promptly give rise to certain psychic processes and movements required to get the right finger to the key desired. This step, locating the key with the fingers, represents in the beginning a very difficult and roundabout process which must be

gone through with for each letter before the final letter-making movement of the finger can be made. In the earliest writing each letter of the copy must be first fixated with the eyes (or spelled), its corresponding key separately located, first with attention, then with the fingers, the letter again actually or incipiently pronounced before or as the key is being struck. As practice continues a "short circuiting" in each part of this five-step process reduces all to one in consciousness. The sight of the letter in the copy, or its mental representative, the spelling, comes to call up at once the one proper letter-making movement, which by careful attention to its details can be properly guided or directed as made. When this has been accomplished a "letter association" has been formed. With continued practice these letter-making movements become easier and easier until little conscious direction is needed for their proper performance. The separate movements for a group of letters representing a frequently recurring syllable or word follow a course of "short circuiting" similar to that which eliminated the separate steps early required in making a letter. The letter making movements begin to need less and less individual guidance and finally drop out of consciousness sufficiently to permit the syllable and word to be reacted to as a whole. In other words a direct association is formed between the sight or inner pronunciation of the oft recurring syllables and words and the total groups of movements required for writing them. The word has now become the unit for attention and is reacted to as formerly were the letters or still earlier the individual steps in the process of making letters, at first in a very detailed way, then more and more generally as the higher-order (word) associations are perfected and phrase associations are formed. As skill increases certain groups of movements representing the syllables and words begin to link themselves together for certain phrases and clauses, attention dealing with the larger group of movements involved in writing as before, first in detail then in a more and more unitary fashion, until the larger group is no more of a task for consciousness than was once the letter and word. A direct association is thus formed for the easy and more familiar phrases.

Similar psycho-physical habits were developed in learning to write by the "sight" method with only such characteristic differences in the process of their formation as was occasioned by the fact that in this method the copy had to be learned and

somehow held in mind until written and the further fact that there was as a result of this a constant shifting of attention from the writing to the process of learning the copy (pp. 52-54). It was the inception, development and final perfection of these habits of every kind and order that caused the rise and upward movement of the curves.

B.

The following facts were obtained concerning the growth and development of these special habits:

1. The special typewriting associations or habits of manipulation are all developed and perfected in a definite manner. The earliest associations employed in the writing are formed from the masses of familiar associations and activities which the learner brings with him to the work. In the beginning the learner's attention and effort cannot be applied to the writing in a direct and economical way. Under the influence of the strong desire to succeed in the new task there are called up masses of old and easy associations and forms of activity, most of which are not directly serviceable for the writing. From these associations and activities is built up by the double process of elimination and selection the first elementary, step-by-step, blundering associations used. By a further process of elimination and a simultaneous one of re-combination, called into action by the extreme exertions of the learners in their eager desire to reach a higher speed and greater facility, their first elaborate and circuituous methods of writing are simplified, refined, changed, until, sheared of some of their accessories, they enter into and form the easiest and most direct method of work yet attained. Throughout the learning there is, if one may so phrase it, a sort of unconscious struggle for existence among many modes of action and methods of work, ending in the survival of the one most direct and economic way of reaching the goal. Some of the early habits called forth by the learning exist but to be eliminated, others enter into and constitute the first simple and direct habits used in the writing. These elementary habits are in turn modified and reorganized, as practice continues, as parts of higher and more economical groupings, in which their identity is gradually merged, while these higher groupings in turn are worked over into yet higher complexes by essentially similar processes.

Three facts of major importance were determined in regard to this process of short circuiting:

(a) The new adaptations or forward steps in the learning were made quite *unintentionally* so far as the subjects were concerned. They were simply fallen into when the conditions were favorable for making a forward step and were executed marginally for sometime before the learners became aware of their presence and value for the work (pp. 95-98). When the advantage of the new method had been noticed it was generally, thereafter, made use of purposely, though even then consciousness seemed to be more of a hindrance than a direct help. As Z expressed it: "I find that I have to let the thing do itself. When a new way of doing the work is noticed and I purposely try to use it or to assist, it never goes right."

(b) The necessary pre-condition for taking a forward step in the learning was extreme effort, carefully applied to the work on a good day, when the older associations had been carefully revived and when the learners were thoroughly "warmed up" (pp. 92-95, 109).

(c) The process of progressive organization and co-ordination of the simpler activities into higher and more economic and direct methods of writing becomes itself more and more difficult as skill increases. In the advanced stages of learning where the elements are more complex, new adaptations become harder to make, first, because the learners have had little or no experience in making higher groupings (as most learners are masters of nothing); second, because, for the lack of success or slower progress, attention naturally tends to drift away from the work, both in its details and as a whole, making the writing in the later stages of learning harder and harder to attend to (pp. 145-146).

2. It was determined in the second place that the special habits of manipulation involved in learning typewriting naturally and normally grow and develop simultaneously, i. e., they literally perfect one another. The elementary habits are not completed before the higher-order habits begin to form. The development of the higher and the perfection of the lower go hand in hand, throughout the whole course of the learning. Lower-order habits are developed in and through the formation of the higher as a further development of the higher is dependent upon the careful and final perfection of the lower (see pp. 85-89).

3. This simultaneity of development does not mean, however, that all the habits of manipulation are making steady gains at the same instant. While all develop together they are not actually driven abreast. The gains made within the realm of each individual association is, like the general progress in learning, unsteady and irregular. The growth and development of the several special habits is something like the movement of a flock of sheep along a country road. The whole flock moves forward, now faster, now slower, while now this now that particular sheep pushes ahead of the rest. In learning typewriting all associations involved are making progress almost from the first. Over this vast array of possibilities of improvement the learner's attention moves, focusing now on this, now on that particular phase of the work and causing an adaptation or short cut to be made now in this, now in that part. Frequent relapses in all departments of the work occur and there is great irregularity in the development of each special association because of the way in which attention changes (pp. 90-91).

4. The final perfection of all the special associations involved in typewriting is a very slow and gradual process. A little attention and direction is needed and must be given for a very long time after the details seem to be completely self-regulative. This fact has two very important bearings on learning: (a) As the association becomes automatic it loses its attraction, or drawing power, for attention and becomes very hard to attend to carefully. (b) This affects the learner's attitude. He either gets lazy and lets attention drift to outside interests, or crowds ahead too fast, aiming at speed, and fails to give to the association the slight direction required to master it fully.

These facts make clear the meaning of the general course of the learning curves. Their first rapid rise is due to the fact that all orders and kinds of associations are developing simultaneously and that they are all in their first stages of development where growth is easy and rapid. The later slow and gradual rise is explained by the fact that many adaptations and combinations have been made, that those which remain are harder to make and that the final perfection of associations is itself such a slow and gradual process. The learning curves become almost horizontal as an expert skill is approached.

C.

We have been treating the factors which account for the general, or as one may say, ideal form of the learning curves. But the actual process of acquiring typewriting habits is less simple than the above account suggests. Many things come in to hinder the growth and development of the habits to be formed, making the actual procedure in the learning far from ideal or steadily continuous, as is so well pictured by the irregularities of our actual learning curves. Among the many factors influencing the formation and development of the special habits acquired in learning typewriting may be mentioned the following:

1. The Daily Relearning and Warming Up.—Some of the skill acquired on a particular day is forgotten and none of the associations work as promptly and easily upon first beginning as afterwards. Old habits cannot be called into use by a sheer act of will, but must be carefully re-exercised to re-establish the chain of sub-conscious reflexes. This daily relearning and reviving of the older associations was found to be intimately connected with the circulation of the blood, since the "warming up" or increase in efficiency, was always accompanied by an increased pulse rate (pp. 105-109). The significance of the relearning and "warming up" for acquisition lies in the fact that both must take place before it is profitable to work with maximum effort. New adaptations cannot be made so long as attention is busy with the slightly faded older associations. As soon as these have been sufficiently revived the learner may with advantage push himself on to higher planes of work.

2. The most important factors influencing the formation of the special habits involved in typewriting are the fluctuations in attention and effort, which occur throughout the course of the learning, and the mistakes fallen into, and changes in feelings and attitude which regularly accompany both of these. Three groups of fluctuations occurred.

(a) Regular and irregular fluctuations in attention and effort occurred throughout the course of every test. The regular fluctuations which occurred were the initial and final spurt in effort (Anfangs—und Schlussantrib), previously observed by Rivers and Kraepelin, Lindley and others (pp.123-130). In addition to verifying their results about this variation in

effort our experiments showed that this initial and final spurt in effort was only present for the periods of practice showing rapid improvement. For the stages where the "plateaus" in the learning curves appear and where the longer regular lapses in attention and effort occur no *Antrieb* and less "warming up" occurred (p. 129). But in addition to these regular variations in attention and effort there were irregular fluctuations lasting from a half to one, two or three minutes of a test, short periods when the learner's efficiency was very much decreased in every respect. The effect of these lapses in efficiency on the work, the manner of their appearance and disappearance, the fact that they were wholly beyond the learner's control and were repeatedly accompanied by definite changes in feelings (p. 122) suggest fatigue as the chief factor in bringing them about. Not the fatigue occasioned by the difficulty of the work alone but that brought on by other causes and depending on the general hygienic condition of the learners at the time of the test.

(b) Marked variations in attention and effort also occurred from day to day—fluctuations revealed by the experimenter's and learner's notes, by the number and kinds of errors made, and by the pulse curves. Lapses in spontaneous attention and effort regularly followed by relaxed voluntary effort or, in rare cases, by increased effort recklessly and ineffectively applied to the work. With these variations regularly went a noticeable dearth of incentives to voluntary effort, definite changes in the learner's affective tone, sometimes marked changes in his physical condition, a relapse into older and more primitive methods of writing, and the complete inability on the part of the learner to control or remedy the defect in efficiency produced—facts which strongly suggest that the daily fluctuations in attention and effort, like the momentary fluctuations, are indices of the learner's general neural tone, and are, therefore, produced by variations in his general mental and bodily condition on that day. This, together with the operation of the law of habit, which allowed the general effects of a good or bad day to accumulate and affect the following day, is responsible for the daily fluctuations in attention and effort. They are related to learning in two principal ways: (1) They help to bring about the longer lapses in attention and effort which occur at irregular intervals throughout the course of the practice (pp. 135-136). (2) On a bad day when spontaneous

attention is relaxed it is profitable to drop down to a lower plane of work, one sufficiently low for the work to be done correctly. Only on the good days is it profitable for the learner to "sprint" or try hard to push himself onto a higher plane of work.

(c) Of still more importance for learning are the *regular* and *irregular* lapses in attention and effort which occur at different stages of practice. At certain irregular intervals definite periods of relaxation occurred, "breathing places" lasting from five to eight days. Anything that retards success temporarily, which dampens the learner's ardor and enthusiasm, and so takes away some of the spontaneous and voluntary incentives to effort, brings about a temporary lapse in attention and effort which by the law of habit may be prolonged for a period of several days (p. 135). These irregular lapses in attention and effort were regularly terminated by the coming in of some special incentive to effort. Only when the relaxation comes on the verge of the longer *regular* lapses is it serious for learning as a whole. At such a time they serve to further aggravate the more serious lapses in attention and effort which occur at the "critical stages." These *regular* lapses in attention and effort have a different cause and should be carefully distinguished from the *irregular* lapses. At certain definite stages of advancement, where a special habit or a group of special habits is being finally perfected two strong and natural tendencies are manifest. (1) Attention naturally drifts away from the work as a whole. (2) The details becoming automatic are slighted in this last stage of their development, because they become harder to hold in attention. This combination of natural causes brings on the longer periods of relaxation in spontaneous attention and effort which regularly tend to occur at the "critical stages" in the learning. We say "critical stages" because the learner is specially liable at such stages to be caught by one or both of the following tendencies: (1) To let his attention drift to outside interests as it naturally tends to do, instead of forging ahead and pushing himself onto a higher plane of work as fast as possible, or (2) he may push himself along too fast, neglecting to give the slight attention to the details still needed to properly master or perfect them. The learner may, however, meet successfully every tendency to lag and to push ahead too fast and keep his progress continuous (pp. 165-166) as all our subjects did at some of the critical stages.

This fact, that attention tends naturally to leave every association in the last stages of its development, where its growth is slow, and the work as a whole when improvement becomes slight is strong evidence in favor of an *instinct of learning.* As long as any gain is made and further progress or acquisition is possible the activity or work naturally holds the attention and awakens interest. Continued attention or application is assured by the pleasurable feelings and favorable attitude which always accompany success. The organism as a whole naturally tends to continue the activity as long as improvement is made. When progress stops the activity (mental and physical) becomes disagreeable and attention goes elsewhere.

3. The fluctuations in attention and effort just described were regularly accompanied by definite changes in the learner's feelings and attitude, and by an increase in certain kinds of errors both of which influence the learning. When lapses in attention and effort occurred more mistakes were made, the kind of errors made being a true index of the kind of fluctuation which occurred (pp. 118-120). The mistakes always had a hurtful retroactive effect on the development of the associations to be formed: (a) By further aggravating the fluctuations themselves, either by calling attention to themselves (i.e., the mistakes) and so taking it off the work, or by filling the mind with unpleasant feelings on their account, or by both. (b) By the practice in error, which they involve and which in the future interferes with the free action of the associations underlying correct writing. The correlation between the learner's general affective tone or attitude and his ability to do and to learn was so close that if one had a complete and accurate record of the changes that occurred in the former he would have an accurate criterion for measuring his efficiency and progress. A high degree of spontaneous attention was always accompanied by a pleasurable feeling tone; a failure in attention and effort by feelings of displeasure and disgust. The exercise of voluntary attention when successful, developed a similar favorable attitude and was always accompanied or immediately followed by feelings of pleasure; if wrongly directed and unsuccessful, this fact aggravated the already unfavorable mood and was followed by feelings of displeasure. Whether the feelings and mental attitude of the learner gave rise to the fluctuations in attention and effort and the consequent failure or success, or whether the fluctuations in attention and effort caused the changes in

feelings, or whether both were a joint effect of a still more fundamental cause, could not be determined from any data obtained. So far as our facts go they show that the feelings do quite as much toward inducing and emphasizing certain fluctuations in attention and effort as *vice versa*. The feelings were a perfect index of the learner's psycho-physical efficiency and of how his attention was working, and always had a stimulating or retarding effect on every part of the work (pp. 149-152).

That the sensations or feelings aroused during a test, as well as the total effects of the practice on any particular day, should accumulate to form the attitude or mood with which the learner approached his work on the following day, and the further fact, that the daily feelings and moods aroused by the work should regularly accumulate to form the attitude towards the work for different stages of practice, is as interesting as it seems significant (compare pp. 152-153).

These fluctuations in attention and effort are responsible for the variations in our learning curves, from minute to minute, from day to day, at the "breathing places" and at the "critical stages."

The minute and daily fluctuations are doubtless unavoidable. The lapses in attention and effort which occur at the "breathing places" and the "plateaus" in the learning curves may be eliminated; there is nothing in their cause that may not be successfully met and some "plateaus" were successfully eliminated by our learners.

The results of our memory tests give special emphasis to the importance of the time intervals in learning and open up the whole problem of determining the most economic periods of work and rest for all kinds of learning. The marked gain shown by our second memory tests was primarily due to the disappearance with the lapse of time of innumerable hindering psycho-physical associations or tendencies, naturally built up in the course of the practice. These with the lapse of time dropped out and left the more firmly established typewriting associations free to act. When it is recalled that at the "critical stages" these hindering associations and tendencies develop, or tend to develop in great masses, and that the feelings which further hamper the work tend to accumulate, and when it is remembered further that great effort is required to push the learner onto a higher plane of work, the significance of vacations for

learning becomes apparent. A period of rest not only removes the *ennui* or fatigue for the work as a whole and the incipient bad habits of attention and the interfering associations to which the fatigue and the work gives rise, proper intervals of rest may allow for a natural neural growth or setting of the habits to be formed that would be more helpful for their development than further practice, even though it be careful and correct. One of the most important problems for all learning is to determine that proportion of practice and rest which will give the best results and to determine more accurately than has hitherto been done what this rest period means for the learner. That such a period is helpful as giving an opportunity for the dropping out of the interfering associations and wrong tendencies which accumulate in the course of the learning of complicated sorts of skill seems certain.

Besides determining the special habits of every kind and order involved in the mastery of typewriting and showing concretely, by a minute history of the learning process, how these habits were developed and perfected as successively organized and recombined into associations and habits that bring the learner always more directly and economically to his goal, this study has shown the important role played in the learning, by *effort* and *hygiene*. Two facts stand out above all the rest: (1) All special habits and associations involved in the mastery of typewriting must be carefully perfected. (2) They must then as rapidly as possible be outgrown and give way to higher and more direct habits of writing. Bryan and Harter were right when they said: "We believe that by no device is it possible to gain freedom in using the higher-order habits until the lower have been so well mastered that attention is not diverted by them." They suggested a truth of still greater importance when they added: "It is, nevertheless, wise at all times to practice with the highest units possible, and thus learn all the units in their proper setting" *(Psy. Rev.,* Vol. VI, 1899, p. 368). The older elementary habits tend naturally and strongly to persist (pp. 94-95) and must be left behind as rapidly as possible to prevent arrest. To try to crowd ahead before the elementary habits are sufficiently mastered to make safe the taking of a forward step, or to fail to perfect the elemental associations which must be combined to form the higher and more direct methods of writing, is fatal to progress or interest. To be caught by the law of habit and continue to think or work on a

low plane when new possibilities of improvement lie ahead is just as fatal. It is, therefore, imperative that the learner should always practice with the highest-order habits he can use. But he must not try to go too fast. Great effort wrongly or carelessly applied is even more detrimental to progress than a simple lapse in attention and effort. Since all the special habits to be formed must be religiously guarded in the last stages of their development to be thoroughly mastered, and since these habits are developed simultaneously and literally perfect each other, and since intense effort is required to make a forward step, the vital problem in learning resolves itself into making the right use of attention and determining how fast to push ahead. The tendency to slight the associations in the last stages of their development and to push ahead too fast, can, of course, best be overcome, in typewriting, by not always practicing at maximum speed, for the effort for speed usually means that attention deserts the details of the work. To perfect carefully the elemental associations it will, therefore, be found better practically, to practice most of the time for accuracy alone and only a small part of the time for speed, a custom generally followed by the best typewriting schools. This would insure the perfection and mastery of the elemental associations and habits. But it is just as essential for progress that the learner should push along as fast as he can and so develop all the habits in their proper setting and avoid falling into a habit of laziness.

The present study has shown that a learner's equilibrium of efficiency varies greatly for different stages of practice. At certain definite stages of advancement where a special habit or group of special habits is being perfected the learners are especially liable to settle down to a rate of work far below their highest possibility, the low rate of efficiency tending to become habitual. In a laboratory experiment in learning and doubtless in all actual learning of the school, the learner's energies in spite of all good will to the contrary are not taxed to their utmost except for a very small part of the time, perhaps never. At certain stages of advancement, especially, the learner is apt to work far within the limit of his best endeavor, he does not work at his maximum rate. His powers of inhibition and control, his ability to manipulate and control his attention, all his mental processes are much contracted, and a habit of working below his optimum possibility is formed; and this occurs because the nat-

ural and strong spontaneous stimuli afforded by the work disappear and no special incentives are made to take their place. The learner's energies, which might be brought to bear in mastering the task are not called forth, an absolute necessity if the learning is to go on at its best rate.

In forced learning, such as is artificially undertaken in the laboratory or schools, the strongest natural incentives to endeavor, such as are afforded by the emergencies of life, are lacking, and not the least problem connected with educational work is to find incentives to effort which will call forth *all* the energy that may be brought to bear on the mastery of the subject studied. That such special incentives and stimuli must be found and used if learning is to go on to the best advantage seems certain from the facts which precede.

The role and significance of *hygiene* for the learning can hardly be over-emphasized. It was found in this study that the number, length, succession and seriousness of the irregular lapses in spontaneous attention and effort that occurred throughout the course of a test depended not alone upon the difficulty of the work, but more upon the hygienic condition of the nervous system and of the body of the learner at the time of the test. It was also found that the fluctuations in efficiency which occurred from day to day meant variations in the general mental and bodily conditions of the learner, that the easiest way to regulate and control them was by an improvement in the learner's general neural tone induced by sleep, rest, exercise, food, change of attitude or mood, by the selection of more favorable weather conditions or by anything else that would improve his hygienic condition. It was found further that these daily lapses in attention and effort were responsible for the longer irregular lapses at the "breathing places" in the curves (pp. 135-136). These facts taken with the following, namely, that the learners could do nothing directly (i.e., by sheer act of will) to control the fluctuations in attention and effort; that the forward steps in the learning were made quite unconsciously, the organism adapting itself to the conditions presented with little help from consciousness; that new adaptations were made only during a good period and on a good day when attention and effort could be spontaneously and vigorously applied to the work—these facts indicate clearly the significance of hygiene for learning and the particular role it plays. It is not what the learner would like to do, but what his mental and physical con-

dition at the time of study or practice will let him do, that is important for determining his progress. The process of learning typewriting is something like mowing a field. The farmer takes out his machine to cut his grass. He can only keep his machine in good condition and vigorously applied to the work; the machine does all the rest. It does its own work in its own way. How well it works depends upon the nature and condition of the machine. So with a learner in typewriting; he begins to learn to use the typewriter. How well he does the work, how rapidly he improves, depends, (1) upon how strenuously he keeps himself applied to the task, (2) upon the *learner,* the mental and physical condition of his organism. He must keep himself in perfect condition and strenuously applied to the work; the organism does all the rest. He needs but to consciously lay hold of and make proper use of the adaptations that are unconsciously fallen into, the habits and associations formed. All this suggests that if one wants to improve at the most rapid rate, he must work when he can feel good and succeed, then lounge and wait until it is again profitable to work. It is when all the conditions are favorable that the forward steps or new adaptations in learning are made. Whether the older associations are at such a time also more rapidly perfected or whether monotonous practice will answer as well in stimulating their growth we cannot say.

APPENDIX

Note on Pulse and Efficiency Curves.

As several times indicated in the text of this study, the efficiency or work curves gven in Figs. VI, IX, X, XI, XII, XIII, XIV were determined by totalling the number of strokes made in each separate minute of all the tests and dividing by the number of tests. The pulse curves were obtained by totalling the working pulse rates for each separate minute of all the tests taken or represented by the period of practice for which the curves were drawn, and dividing in each case by the number of tests represented. Mean variations for the averages represented by these curves have not been given because they would give no sort of indication of the reliability of these averages and would be misleading. The pulse was so materially influenced by the weather, as the season and tests progressed (compare table V, p. 135), that the M. V. for the pulse averages would clearly be unreliable and misleading. The M. V. for the averages representing the amount of work done in each minute of the several tests would be more misleading still and wholly useless for showing the reliability of our averages. The increase in skill from week to week and month to month would make the M. V.'s here abnormally large. That our curves do, however, show the effect of a constant factor may be inferred from the fact that the M. V.'s worked out on a percentage basis for the two shorter periods of practice (Z's regular S. M. practice, and for Y's writing of a practice sentence) gave no indications of responsibility for the variations shown by their efficiency curves. We have, therefore, assumed without complete numerical proof that our work and pulse curves do represent the influence of a constant factor. A careful comparison of the tables from which the data for the averages was taken (compare sample records, table IV, p. 124) gave unmistakeable evidence that this was the case. Comparing the variations in our curves with the figures of the tables and determining the tendency to correlation, i. e., counting the cases to determine the percentages of times in which the original data for the pulse and efficiency curves showed a change in the same direction, a strong positive correlation was found for the important variations in all our pulse and efficiency curves. If the variations shown by our averages had been due to accidental factors, this would not have been the case.

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